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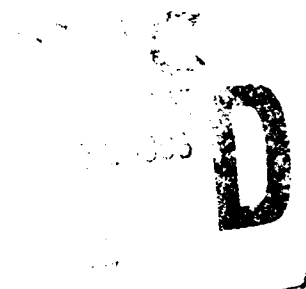
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**US Army Corps
of Engineers**
Waterways Experiment
Station

Evaluation of Upland Disposal of Oakland Harbor, California, Sediment

Volume II: Inner and Outer Harbor Sediments

*by C. R. Lee, D. L. Brandon, H. E. Tatem,
J. W. Simmers, J. G. Skogerboe, R. A. Price,
J. M. Brannon, M. R. Palermo, T. E. Myers
Environmental Laboratory*



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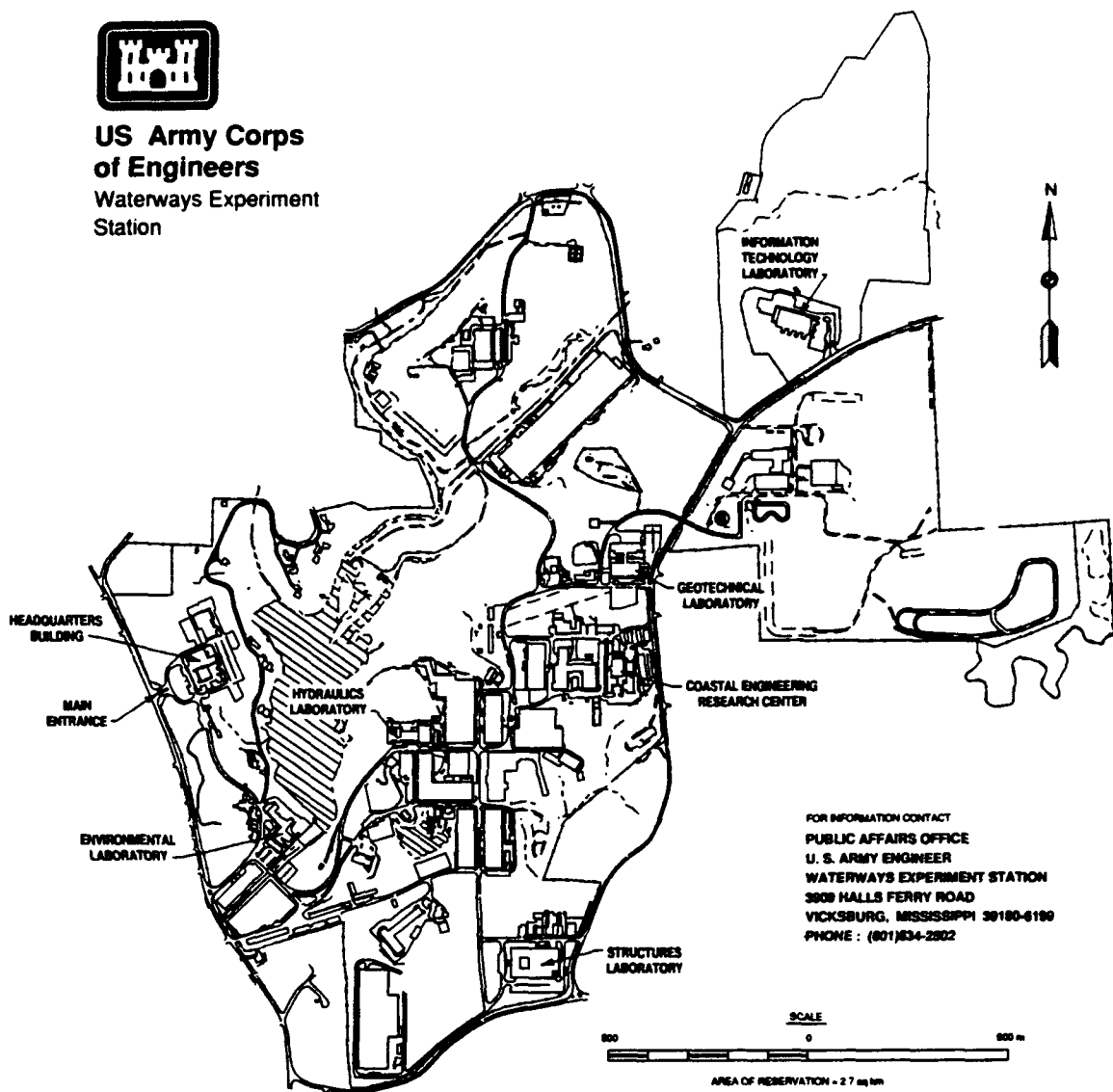
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SUMMARY

Construction of both the Oakland Outer Harbor Deepening Project and the Oakland Inner Harbor Deepening Project were authorized by the Water Resources Development Act of 1986, 99th Congress, 2nd Session, Public Law 99-662 (U.S. Army Corps of Engineers (USACE) 1987). Modifications to the authorized plan were made in 1987 to reduce the amounts of material dredged to 2.8 and 3.7 million cubic yards for the Oakland Outer Harbor and the Oakland Inner Harbor, respectively (USACE 1987).

Sediments in Oakland Inner and Outer Harbors were sampled and tested in 1987-1988 to evaluate the potential for impacts during disposal operations at the proposed Alcatraz disposal site. All material was found to be suitable for unrestricted open-water disposal, except samples collected from the turning basin area of the Oakland Inner Harbor. The turning basin sediments were determined to be unsuitable for unrestricted open-water disposal by a joint USACE and U.S. Environmental Protection Agency (EPA) Technical Review Panel in May 1988, and were evaluated in 1989-1991 by Lee et al. (1992) for upland disposal. The remaining Oakland Inner and Outer Harbor sediments, while suitable for open-water disposal in 1988, were retested in 1990-1991 and evaluated for all disposal alternatives of open-water disposal, wetland creation, and upland disposal.

The U.S. Army Engineer Waterways Experiment Station was asked to assist in the evaluation of the two alternatives, wetland creation and upland disposal, for the remaining sediments from Oakland Inner and Outer Harbors. Francingues et al. (1985) and Lee et al. (1991) described the Corps' Management Strategy for Disposal of Dredged Material, in which a sediment is tested and evaluated for potential disposal site environments, including aquatic, wetland, and upland. These test protocols are included in USACE/EPA (1992) and were used in the present evaluation to determine the potential for migration of contaminants into effluent, surface runoff, leachates, plants, and animals under upland disposal conditions. The evaluation of wetland creation with these sediment is the subject of another report (Lee et al. 1993) and the open-water testing was conducted by Battelle/Marine Science Laboratory at Sequim, WA.

One composite sediment from Oakland Inner Harbor and from Oakland Outer Harbor was tested. The composite sample consisted of sediment cores taken from the mud line to 44-ft depth. Both Oakland Harbor sediments had clayey

sand textures. Total organic carbon (TOC) concentrations in sediment from Oakland Inner and Outer Harbors were 3,364 and 6,042 mg/kg.

Metal concentrations in Oakland Inner and Oakland Outer Harbor sediments were compared to the Twitchell Island soil concentrations from a previous evaluation. Most of these metals are not unusually elevated, but chromium and lead in both Oakland Inner and Outer Harbor sediments appear to be higher than the chromium and lead at Twitchell Island and in the levee soils collected from Twitchell Island.

Butyltin concentrations in Oakland Inner and Outer Harbor sediments appeared to be elevated in comparison to the Twitchell Island soils but were much less than the concentrations of butyltins found in the turning basin sediment of Oakland Inner Harbor (Lee et al. 1992).

Oakland Inner and Oakland Outer Harbor sediments appear to contain lower concentrations of polycyclic aromatic hydrocarbons (PAHs) than previous tested Twitchell soils. Pesticide concentrations in Oakland Inner and Outer Harbor sediments were in the low parts per billion range.

Test results were interpreted in relation to existing Federal criteria and/or State standards, or existing related data and information from literature and past or present research projects. Because the disposal site is not known, test results of water quality data from filtered water samples were evaluated in relationship to Federal Water Quality Criteria and/or State Water Quality Standards for effluents and receiving waters. Test results were compared to the EPA Acute Water Quality Criteria for the Protection of Aquatic Life (USEPA 1987), and the Effluent and Receiving Water Limitations for Waste Discharge issued by the California Regional Water Quality Control Board in response to a permit application by the Port of Oakland for the disposal of Oakland Harbor sediment as levee-building material at Twitchell Island in the Sacramento River Delta. In the absence of State Water Quality Standards for an undetermined disposal site, the Federal Water Quality Criteria were assumed to be applicable to give some perspective to test results. Section 401 requires compliance with State Water Quality Standards, rather than Federal Water Quality Criteria. Final effluent limitations will be determined by the state under Section 401 of the Clean Water Act based on the local water quality objectives applicable to the area where the sediment is placed. These laboratory tests give predictions of water quality for specific conditions and should be considered an indication of the potential of an effluent, surface runoff, or leachate to meet or exceed applicable water quality standards.

Effluent test results indicated that, with the exception of copper and tributyltin, the dissolved concentrations of all contaminants discharged as effluent will meet all assumed water quality criteria or standards prior to any mixing. The concentrations of dissolved contaminants exceeding the assumed criteria or standards (i.e., copper and tributyltin) will require a dilution of up to 2 for Oakland Inner Harbor sediment and 21 for Oakland Outer Harbor sediment in the mixing zone to meet the criteria or standards. This degree of mixing can generally be achieved within a short distance of the effluent discharge.

The salinity of the effluent could potentially cause some adverse environmental impacts. A dilution of 10 would reduce the salinity to less than 2 ppt and would minimize any impacts due to salinity.

Bioassay tests indicated no toxicity associated with exposure of sensitive test organisms to the Oakland Inner or Outer Harbor sediment modified elutriates.

Contaminants in surface runoff from the Oakland Inner and Outer Harbor sediments were mostly bound to the sediment particulates. Significant quantities of arsenic, cadmium, chromium, copper, zinc, and tributyltin could be eroded from an upland disposal site during the wet, unoxidized stage if the suspended solids were not removed from the runoff.

Potential migration of contaminants in surface runoff water during the wet, unoxidized period of upland disposal would be mostly associated with erosion of particulates. Management of the upland disposal site, to remove particulates from surface runoff, would remove 90 to 99 percent of all contaminants in surface runoff. Only soluble copper concentrations in runoff from the Oakland Inner Harbor sediment exceeded the assumed EPA acute water quality criteria for marine environments, and soluble arsenic exceeded the assumed Receiving Water Quality Limitation standards. Soluble arsenic concentrations exceeded the assumed Receiving Water Quality Limitation standards in runoff from the Oakland Outer Harbor sediment, but copper did not exceed the assumed EPA criteria. Consideration of a mixing zone at the discharge point from the upland disposal site and/or further treatment may be required for those soluble contaminants. A mixing zone ratio of about 10 to 1 (receiving water to runoff water) would be required to dilute arsenic concentrations in surface runoff water to the assumed Receiving Water Quality Limitation standards. A ratio of 3 to 1 would be required to dilute copper concentrations to the assumed EPA water quality criteria for marine environments.

Potential contaminant migration in surface runoff from dry, oxidized sediments should occur only from copper, chromium, zinc, cadmium, and arsenic bound to the suspended solids. Only soluble arsenic exceeded the assumed Receiving Water Quality Limitation standards in both sediments. Consideration of a mixing zone or removal of the suspended solids should eliminate the need for further restrictions, particularly with regard to treatment of soluble contaminants. Establishment of vegetation either by natural succession or by planting would further reduce contaminant concentrations in surface runoff. A mixing zone of less than 10 to 1 would be required to dilute unfiltered contaminant concentrations to less than or equal to the strictest assumed criteria or standard, and a mixing zone of about 2 to 1 would be required for soluble arsenic.

Exposure of sensitive bioassay test animals to Oakland Harbor sediment runoff waters showed little potential for aquatic toxicity. Mean survival was usually greater than 90 percent for all treatments, even for animals exposed to 100 percent runoff water.

The oxidation of Oakland Harbor sediment resulted in increased leaching of metals compared to anaerobic sediment. The increase in metals leaching was not extremely high, but leaching under aerobic conditions indicates that leachate metals concentrations will be higher if dredged material in an upland facility is drained to the extent that oxidizing conditions exist throughout the dredged material. From a management perspective, these results indicate that metals mobility can be reduced by maintaining anaerobic conditions.

Maximum Contaminant Levels established under the Safe Drinking Water Act were not exceeded by any of the leachate data. The assumed Effluent or Discharge Limitation standards for copper and tributyltin were exceeded in at least one leaching test for Oakland Inner and Outer Harbor sediments. The assumed Effluent Limitation standards for cadmium and zinc also were exceeded for the Oakland Inner Harbor sediment leachates. The assumed Receiving Water Quality Limitation standards were exceeded for all contaminants with the exception of chromium for both Oakland Harbor sediments and zinc in the Oakland Inner Harbor sediment.

The plant bioassay test indicated that plant growth on either Oakland Inner or Outer Harbor sediment was poor. Tissue contents of cadmium, lead, and selenium appeared to be elevated in plants grown in Oakland Outer Harbor sediment and should be of concern. Consequently, consideration of restrictions and controls is warranted for plants colonizing Oakland Outer Harbor

sediment placed in an upland disposal environment. Plants should be limited to nonagricultural species that minimize uptake, such as red fescue. Upland disposal of Oakland sediments are not expected to contribute to plant uptake of PAHs and butyltin that would be of environmental concern.

Both Oakland Harbor sediments were not toxic to earthworms after sediment salinity was reduced by washing (leaching). Initially, the sediment would be toxic to earthworms in the disposal area. However, after the salt has leached out, the sediment would no longer be toxic to earthworms. If salts were washed out of the sediment prior to disposal, no toxicity to earthworms would be observed. While earthworms survived in both Oakland Harbor sediments, they showed reduced weights compared to those in the manure reference. To obtain chemical analysis of earthworm tissues, composite samples of replicates were made. There is a potential for soil invertebrates to bioaccumulate arsenic to concentrations equal to or above the Australian action level (similar to that of the U.S. Food and Drug Administration (FDA)) of 10 $\mu\text{g/g}$ for shellfish and fish. Foodwebs may become contaminated with arsenic at the upland disposal site. It is noteworthy that snails collected in the San Francisco Bay area contained 17 $\mu\text{g/g}$ arsenic as a background tissue concentration (Lee et al. 1993). These data suggest a relatively high ambient arsenic concentration in the environments around San Francisco Bay. There is some potential for metals such as cadmium to move through the herbivore food chain, but not into insectivores (Stafford et al. 1991). A monitoring plan should be employed to evaluate the mobility of metals such as arsenic, nickel, and cadmium in the ecosystems that are allowed to become established on an Oakland Harbor sediment upland disposal facility in both the short and long term.

There is no information concerning the potential movement of butyltins from soil invertebrates into the terrestrial food web. Insectivores and small herbivores should be sampled for butyltin content as the site is naturally colonized, or the disposal area should be planted with vegetation that deters colonization by birds and mammals.

Movement of polychlorinated biphenyls (PCBs) from soil invertebrates to higher organisms, such as insectivorous birds, does not appear to pose any problem (Stafford et al. 1991). However, there are no data concerning the movement of PCBs in the herbivore food web. Tissue PCB concentrations in earthworms exposed to Oakland Harbor sediments were an order of magnitude below FDA action levels for shellfish and fish. For perspective, earthworms

exposed to the contaminated reference (i.e., Field Verification Program dredged material) contained tissue PCB concentrations equal to or above the FDA action level of 2,000 $\mu\text{g}/\text{kg}$ and would be of concern.

Levels of pesticides in bioassay earthworms were relatively low when FDA action levels are considered. Levels of PAHs in bioassay earthworm tissues appear to suggest the need for management practices to isolate these compounds from food webs that may become established on the dredged material.

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PREFACE

This report presents the results of an evaluation of upland disposal of sediment from Oakland Harbor, California, performed for Mr. Brian Walls and Mr. Duke Roberts, project managers at the U.S. Army Engineer District, San Francisco.

The study was conducted by the U.S. Army Engineer Waterways Experiment Station (WES). Work was performed by Dr. Charles R. Lee, Soil Scientist, Mr. Dennis L. Brandon, Statistician, Dr. Henry E. Tatem, Zoologist, Dr. John W. Simmers, Research Biologist, Mr. John G. Skogerboe, Physical Scientist, Mr. Richard A. Price, Agronomist, and Dr. James M. Brannon, Research Chemist, of the Environmental Processes and Effects Division (EPED), and Dr. Michael R. Palermo, Research Civil Engineer, and Mr. Tommy E. Myers, Environmental Engineer, of the Environmental Engineering Division (EED), Environmental Laboratory (EL).

The authors wish to thank several individuals for their technical assistance in mixing sediment, conducting various tests, and harvesting test specimens. These individuals include contract students Mr. Antoine Bargins, Mr. Keith Fessel, Mr. Andrew Green, Ms. Heather Holifield, Ms. Elizabeth Huie, Mr. Johnny McGuffie, Mr. Michael Pendarvis, Ms. Erika Seals, and Ms. Elizabeth Tominey; Ms. Cynthia Price of EPED; and Mr. Lawrence Bird of ASci Corporation. Chemical analyses of sediment, water, and tissues were performed by Dr. Eric Crecelius, Battelle/Marine Sciences Laboratory, Sequim, WA. Sediments were collected by Dr. J. A. Word, Mr. J. C. Coley, and Mr. L. D. Antrim, Battelle/Marine Sciences Laboratory, Sequim, WA.

The work was conducted under the supervision of Dr. Bobby L. Folsom, Jr., Chief, Fate and Effects Branch; Mr. Donald L. Robey, Chief, EPED; Dr. Raymond L. Montgomery, Chief, EED; and Dr. John Harrison, Director, EL.

At the time of publication of this report, Dr. Robert W. Whalin was Director of WES and COL Bruce K. Howard, EN, was Commander.

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PART I: INTRODUCTION

Background

Construction of both the Oakland Outer Harbor Deepening Project and the Oakland Inner Harbor Deepening Project were authorized by the Water Resources Development Act of 1986, 99th Congress, 2nd Session, Public Law 99-662 (USACE 1987).

The plan authorized for Oakland Outer Harbor in 1986 called for widening and deepening of the existing 3.4 mile Oakland Outer Harbor Channel to -42 feet MLLW (Figure I-1). This plan would require the dredging of approximately 4.9 million cubic yards of bottom sediments, which were proposed for disposal at the Alcatraz Site SF-11 during ebb tide cycle. Annual maintenance dredging and disposal would be required for an additional 88,000 cubic yards of material.

The authorized plan for Oakland Inner Harbor called for deepening the existing navigational channels from -35 feet to -42 feet MLLW, between the Oakland Inner Harbor Entrance Channel and the Clay Street Pier at Project Mile 4.4 (Figure I-1). This plan would require the dredging and disposal of 4.4 million cubic yards of material, which were proposed for disposal at Alcatraz. Annual maintenance dredging and disposal would be required for an additional 70,000 cubic yards of material.

Modifications to the authorized plan were made in 1987 to reduce the amounts of material dredged to 2.8 and 3.7 million cubic yards for the Oakland Outer Harbor and the Oakland Inner Harbor, respectively (USACE 1987).

Sediments in Oakland Inner and Outer Harbors were sampled and tested in 1987-1988 to evaluate the potential for impacts during disposal operations at the proposed Alcatraz disposal site. All material was found to be suitable for unrestricted open-water disposal, except samples collected from the turning basin area of the Oakland Inner Harbor. The turning basin sediments were determined to be unsuitable for unrestricted open-water disposal by a joint U.S. Army Corps of Engineers and USEPA Technical Review Panel in May 1988, and were evaluated in 1989-1991 by Lee et al. 1992 for upland disposal. The remaining Oakland Inner and Outer Harbor sediments, while suitable for open-water disposal in 1988, were retested in 1990-1991 and evaluated for all disposal alternatives of open-water disposal, wetland creation and upland disposal.

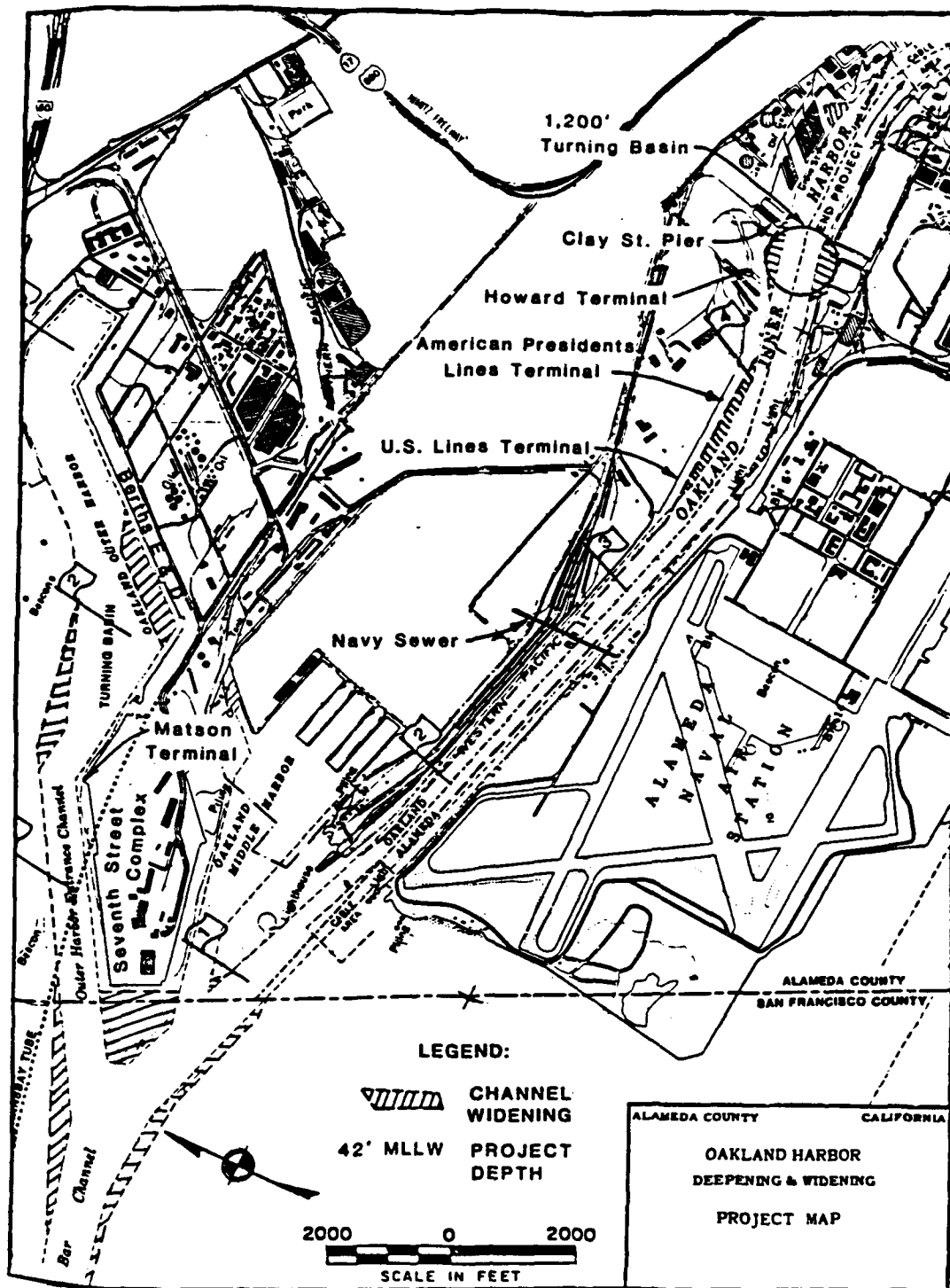


Figure I-1. Oakland Harbor Deepening and Widening Project Map

The U.S. Army Engineer Waterways Experiment Station (WES) was asked to assist in the evaluation of the two alternatives of wetland creation and upland disposal for the remaining sediments from Oakland Inner and Outer Harbors. Francingues et al. 1985 and Lee et al. 1991 described the Corps' Management Strategy for Disposal of Dredged Material, in which a sediment is tested and evaluated for potential disposal site environments, including aquatic, wetland and upland. These test protocols are included in USACE/EPA (1992) and were used in the present evaluation to determine the potential for migration of contaminants into effluent, surface runoff, leachates, plants and animals under upland disposal conditions. The evaluation of wetland creation with these sediment is the subject of another report (Simmers et al. 1993) and the open-water testing is being conducted by Battelle Northwest/Marine Science Laboratory at Sequim, WA.

The Corps management strategy has been applied in total or in part to the following dredging projects:

- Everett Homeport Project, WA
- Black Rock Harbor, CT
- Indiana Harbor, IN
- Blue River Project, Kansas City, MO
- New Bedford Harbor, MA
- Baltimore Harbor, MD
- Southwest Pass, LA
- Corpus Christi Harbor, TX
- Bridgeport Harbor, CT
- Oakland Harbor, CA
- Duwamish Waterway, WA
- Michigan City Harbor, IN
- Detroit River, MI
- Menominee River, WI
- Milwaukee Harbor, WI
- Times Beach CDF Site, Buffalo, NY
- Toledo Harbor CDF, Toledo, OH
- Benton Harbor, MI
- Acid Mine Spoil Restoration, Ottawa, IL
- Dike 12 CDF, Cleveland, OH
- Lock and Dam 2, St. Paul, MN
- Pointe Mouillee, MI
- Broekpolder, Rotterdam, The Netherlands

The Corps management strategy test protocols have also been applied to a number of other contaminated sites such as:

- Naval Weapons Station, Concord, CA
- Naval Subbase, Bangor, WA
- PCB Spill Site, Delft, The Netherlands
- Metal Mining Waste Sites, Wales, United Kingdom
- Agricultural Sites, Haren, The Netherlands
- Wetland Sites, Eastern Scheldt, The Netherlands

Sewage Sludge Amended Soils, Beltsville, MD
Roadside Contamination Sites, Chicago, IL
Agricultural Sites, Montepellier, France
Wetland Sites, Lisbon, Portugal

Test results have been used to evaluate potential contaminant migration and to formulate management strategies and/or remedial actions at these sites.

Purpose and Scope

The purpose of this report is to describe the results of a comprehensive evaluation of the impact of placing Oakland Inner and Outer Harbor sediment in an undetermined upland disposal environment. The evaluation considered contaminant migration via effluent, surface runoff, leachate, and plant and animal uptake. Contaminants of concern were salt, metals, tributyltin (TBT), polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). Because of the scarcity of data on contaminant migration from Oakland Harbor sediments when placed in an upland environment, all contaminants of concern were considered. The data from this evaluation will expand the data collected by Lee et al. 1992, Volume I: Oakland Inner Harbor Turning Basin Sediments.

Test results were interpreted in relation to existing Federal criteria and/or State standards, or existing related data and information from literature and past or present research projects. Because the disposal site is not known, test results of water quality data from filtered water samples were evaluated in relationship to Federal Water Quality Criteria and/or State Water Quality Standards for effluents and receiving waters. Test results were compared to the EPA Acute Water Quality Criteria for the Protection of Aquatic Life (USEPA 1987), and the Effluent and Receiving Water Limitations for Waste Discharge issued by the California Regional Water Quality Control Board (CRWQCB) in response to a permit application by the Port of Oakland for the disposal of Oakland Harbor sediment as levee building material at Twitchell Island in the Sacramento River Delta. In the absence of State Water Quality Standards for an undetermined disposal site, the Federal Water Quality Criteria were assumed to be applicable to give some perspective to test results. Section 401 requires compliance with State Water Quality Standards, rather than Federal Water Quality Criteria. Final effluent limitations will be determined by the state under Section 401 of the Clean Water Act based on the local water quality objectives applicable to the area where the sediment is placed. These laboratory tests give predictions of water quality for specific conditions and should be considered an indication of the potential of an

effluent, surface runoff or leachate to meet or exceed applicable water quality standards.

Test data will be discussed in terms of statistical differences. The word statistical is used to describe differences measured at the $P = 0.05$ level of significance using standard statistical procedures that consider variability in test data to separate data means or a one tailed t-test when criteria or standard values were used. While some scientists have suggested the use of higher levels of significance such as $P = 0.10$ to imply ecological significance to test data, this was not done in this evaluation. Instead, the use of the words "significant" and/or "substantial" increase or amount was used to describe the magnitude of an increase or amount and will be interpreted in this report to mean that the increase or amount is important ecologically.

PART II: SEDIMENT CHARACTERIZATION

Methods and Materials

Sediment Collection, Transport, and Mixing

Sediment was collected in June 1990 from Oakland Inner (OH11) and Outer (OHO) Harbors (Figures I-1 and II-1) using a vibracoring sampler (See Appendix A and Ward et al. 1992a for further details). Samples I-C1 to I-C18 were labeled as composite AC-1 by Battelle. Samples O-C1 to O-C13 were labeled as composite AC-3 by Battelle (Ward et al. 1992a, Ward et al. 1992b). WES labeled these composites OH11 and OHO, respectively. Sediment from core depths to 44 feet was composited into 55 gallon barrels. All barrels of collected sediments were loaded into a refrigerated truck and transported to the WES within 4-5 days. The barrels were placed in a 4 °C cold storage room for 5 days prior to mixing.

Barrels of each sediment were removed from the cold storage room and poured into a lined 4x15x4 feet soil bed lysimeter (Figure II-2). The sediment was mixed by hand with shovels and mechanically with a lightning mixer (Figures II-3 and II-4). After mixing, subsamples were randomly collected from the entire soil bed for use in the different test protocols (Figures II-5 and II-6). Mixed sediment samples were containerized and stored in a cold (4 °C) storage facility until used (Figures II-7 and II-8). Soil beds were covered for protection prior to initiation of surface runoff tests (Figure II-9). Sediments were air dried in aluminum drying flats prior to upland tests (Figures II-10, and II-11).

Sediment mixing was evaluated by collecting aliquot samples from each barrel labelled for each upland test or the soil bed after the mixing process. After mixing all barrels of sediment as shown in Figures II-2 through II-6, subsamples of sediment were collected to be used for separate tests of elutriate (EL), surface runoff (SR), plant bioassay (PL), leachate tests (LE), and animal bioassay (AC). Aliquots of sediment were collected from each container for these tests and analyzed for %sand, %silt and %clay, pH, copper, and total organic carbon (TOC), to evaluate how well the composite sediment was mixed and the uniformity of sediment to be used by the five separate upland tests.

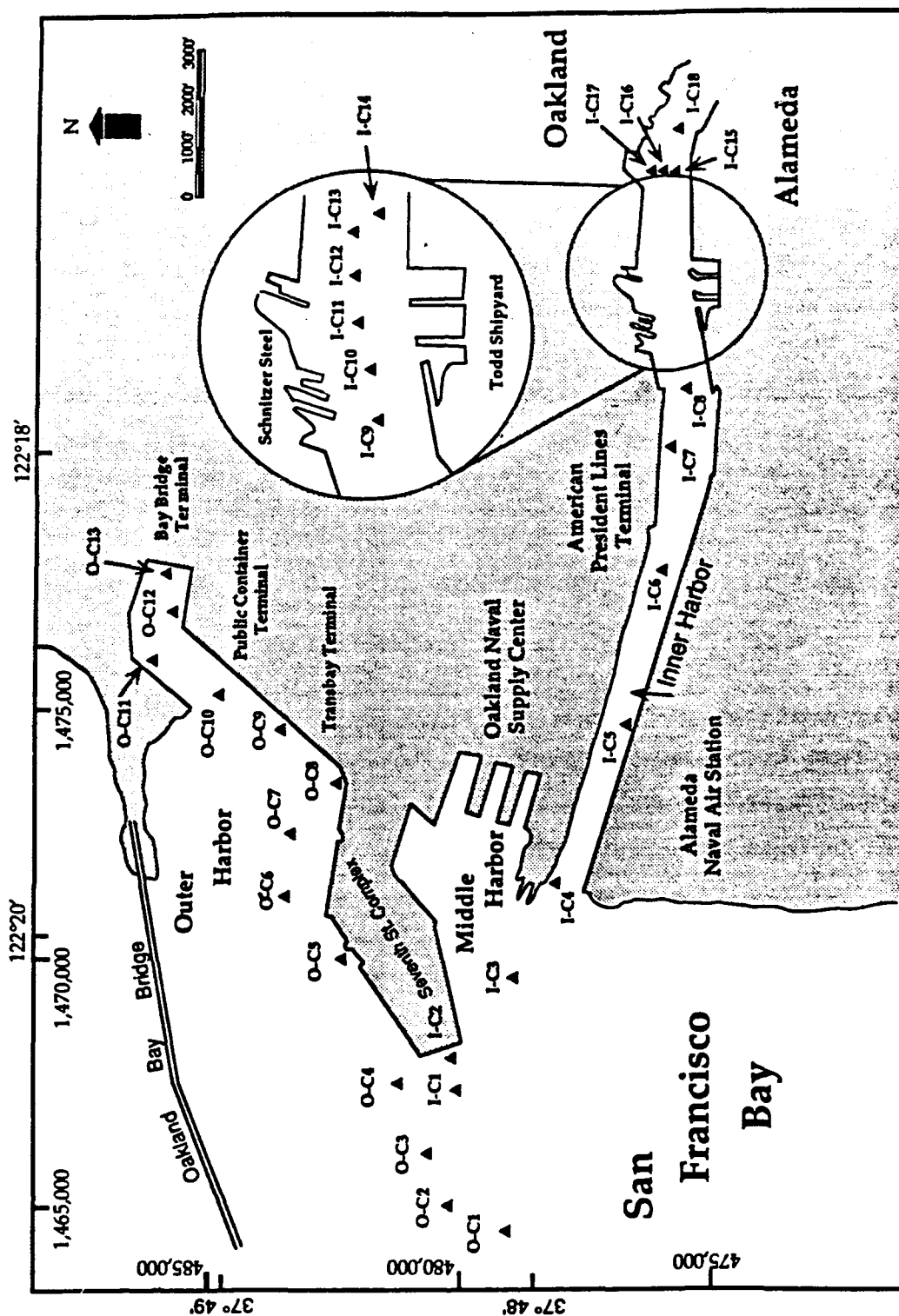


Figure II-1. Location of Sediment Core Sampling Stations

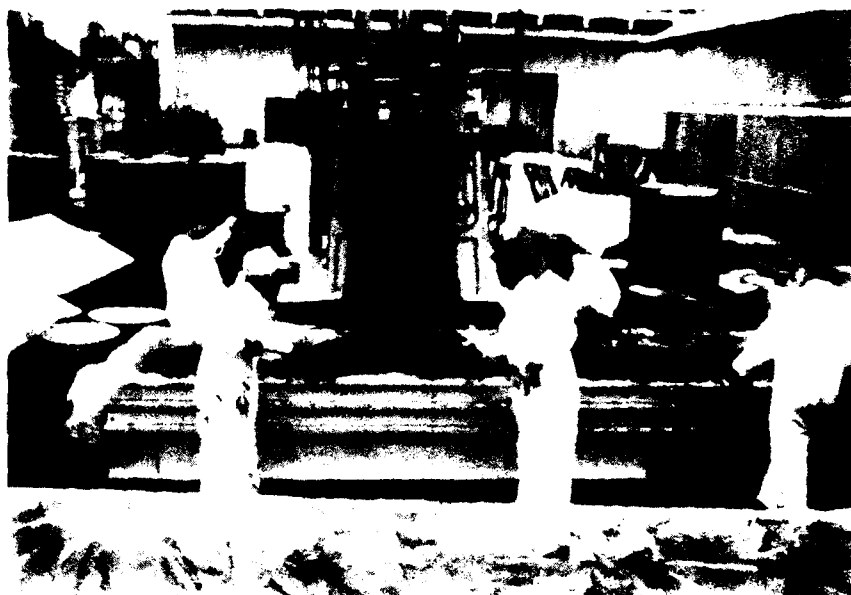


Figure II-2. Barrels Were Emptied Into Soil Bed Lysimeter For Mixing



Figure II-3. Sediment Was Mixed Manually With Shovels, Rakes and Hoes

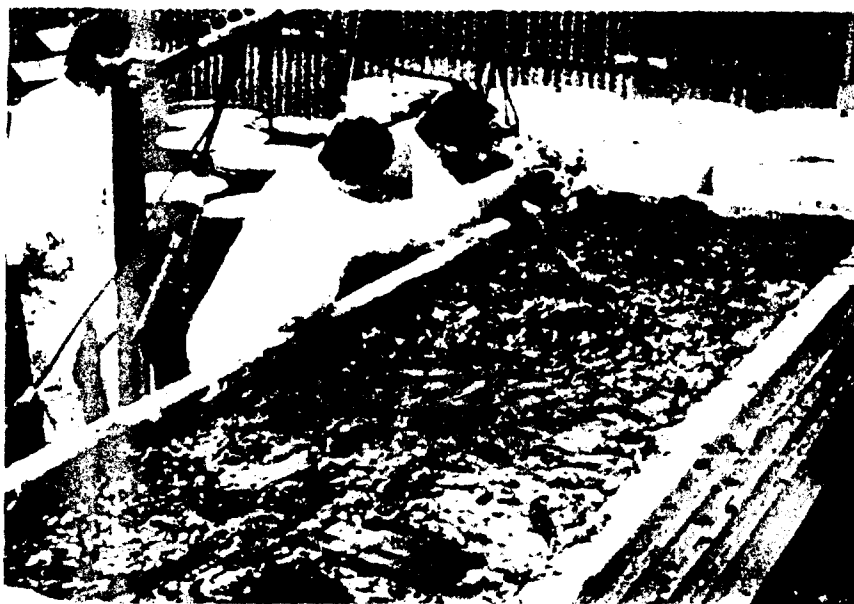


Figure II-4. A Lightning Mixer Was Used To Thoroughly Mix Sediment

Physical Sediment Characterization

Sediment samples were tested for engineering properties such as liquid limits, plastic limits, void ratio water content, density, particle size distribution, consolidation and settling, according to procedures described in Engineer Manual 1110-2-5027 (U.S. Army Corps of Engineers 1987).

Sediment and Soil Chemical Characterization

Replicate sediment samples were shipped to Dr. Eric Greclius at Battelle PN Laboratories, Sequim, WA for chemical analyses. Analytical methods were similar to methods discussed in a previous Oakland report (Lee et al. 1992). Oakland Inner and Outer sediments were analyzed for 10 metals (Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, and Zn), 4 butyltins (tetra, tri, di, and mono), polychlorinated biphenyls (PCBs) as Aroclors, 19 pesticides and 15 polycyclic aromatic hydrocarbons (PAHs). All data received from the analytical laboratory are presented in Appendix A.

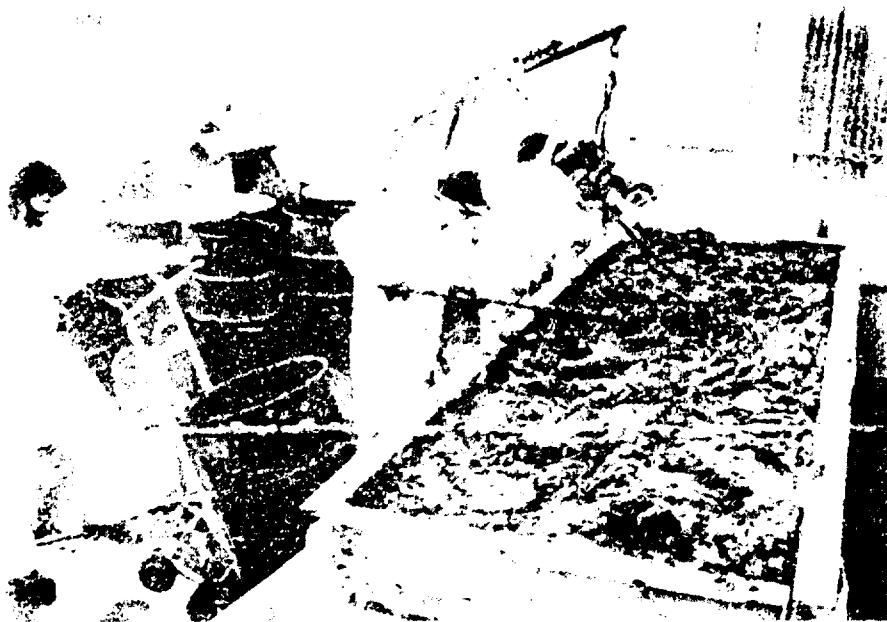


Figure II-5. Random Samples Were Removed From the Soil Bed Lysimeter and Placed in Barrels



Figure II-6. Additional Samples Were Randomly Collected From All Sections of the Soil Bed Lysimeter For Individual Tests



Figure II-7. Mixed Sediments Were Collected in Barrels and Taken To a Refrigerated Building,



Figure II-8. Barrels of Mixed Sediment Were Placed in a Refrigerated Room at 4 °C Until Tested

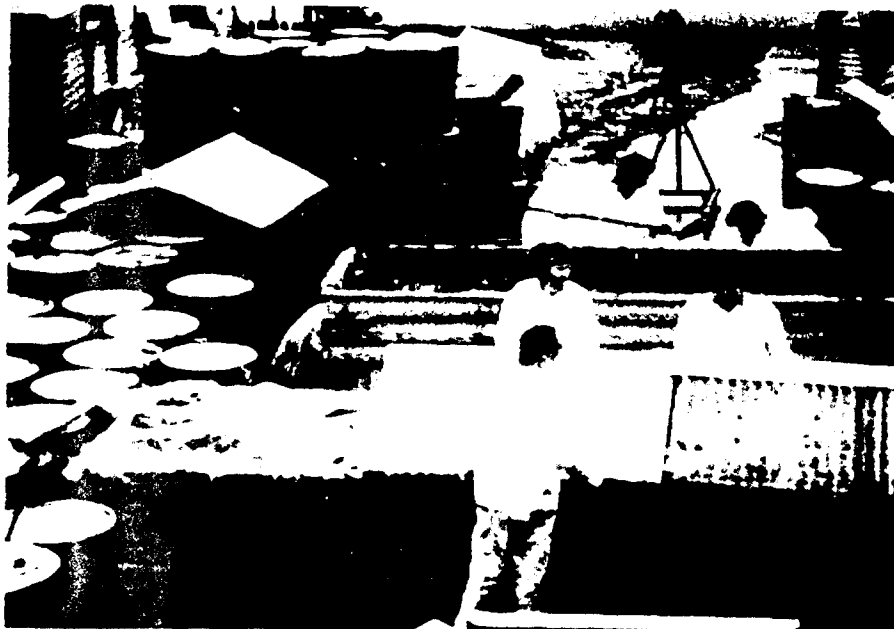


Figure II-9. Soil Beds Were Covered After Mixing

Results and Discussion

Adequacy of Mixing Composite Sediment

Sediment mixing was evaluated by collecting aliquot samples from each barrel labelled for each upland test or the soil bed after the mixing process. The coefficients of variation were below 10% in all parameters except TOC; these were 11.2% and 11.58% for Oakland Outer Harbor and Oakland Inner Harbor sediments, respectively (Table II-1). Normally, coefficients of variability of 10% or less are observed in good controlled experimentation. Since TOC values are large numbers (in the thousands) one would expect increased percentages in coefficients of variability.

Physical Sediment Characterization

Both the Oakland Inner and Outer Harbor sediments had a clayey sand (SC) texture according to the Unified Soil Classification System. Physical properties for each composite are shown in Figures II-12 and II-13 for Oakland Outer Harbor and Oakland Inner Harbor, respectively. Additional engineering properties for consolidation and settling are included in Appendix A.



Figure II-10. Oakland Sediment was Placed in an Aluminum Drying Flat to Dry and Oxidize Prior to Plant and Animal Bioassay



Figure II-11. Dried and Oxidized Oakland Sediment

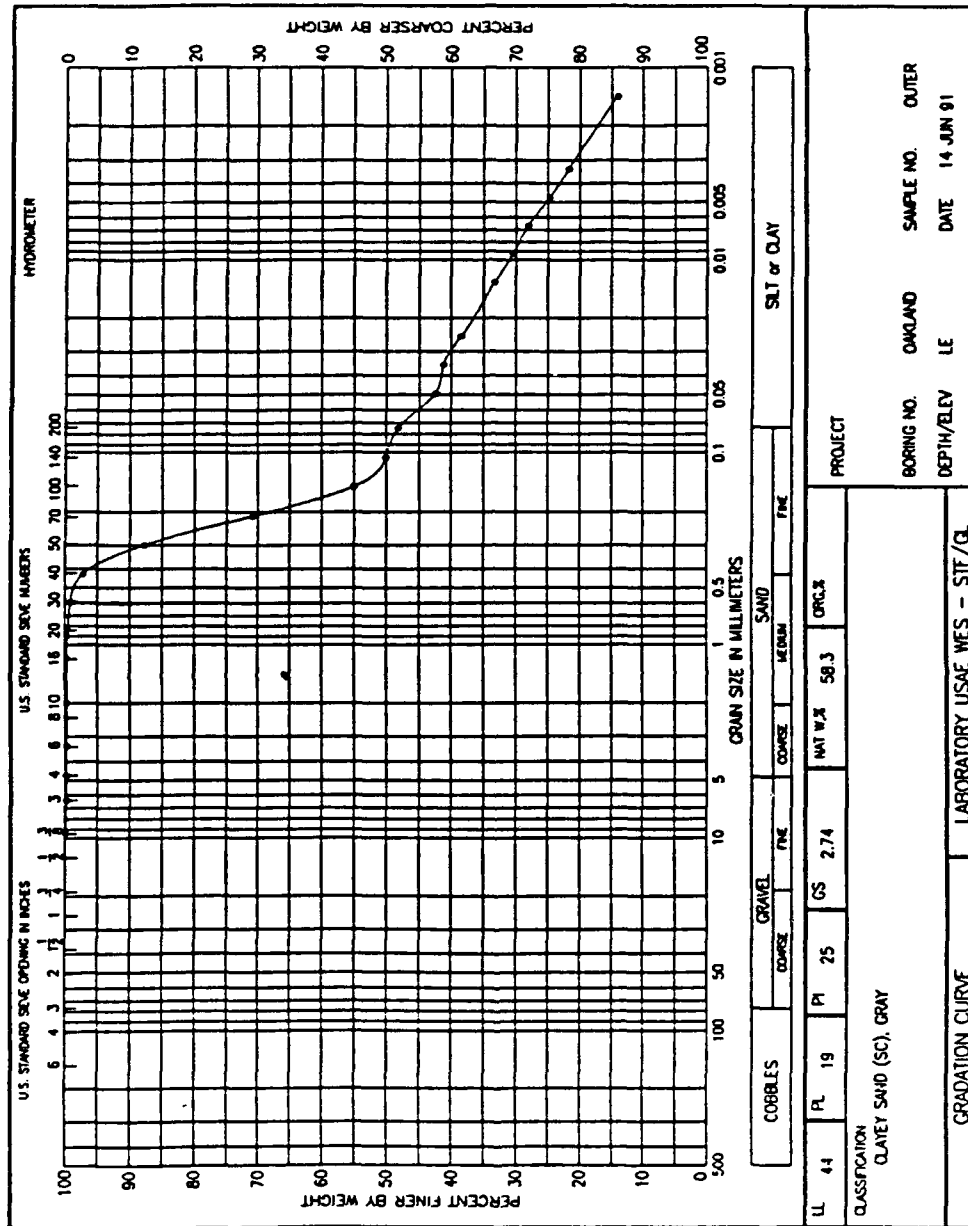


Figure II-12. Physical Engineering Properties of Oakland Outer Harbor Sediment (OHO)

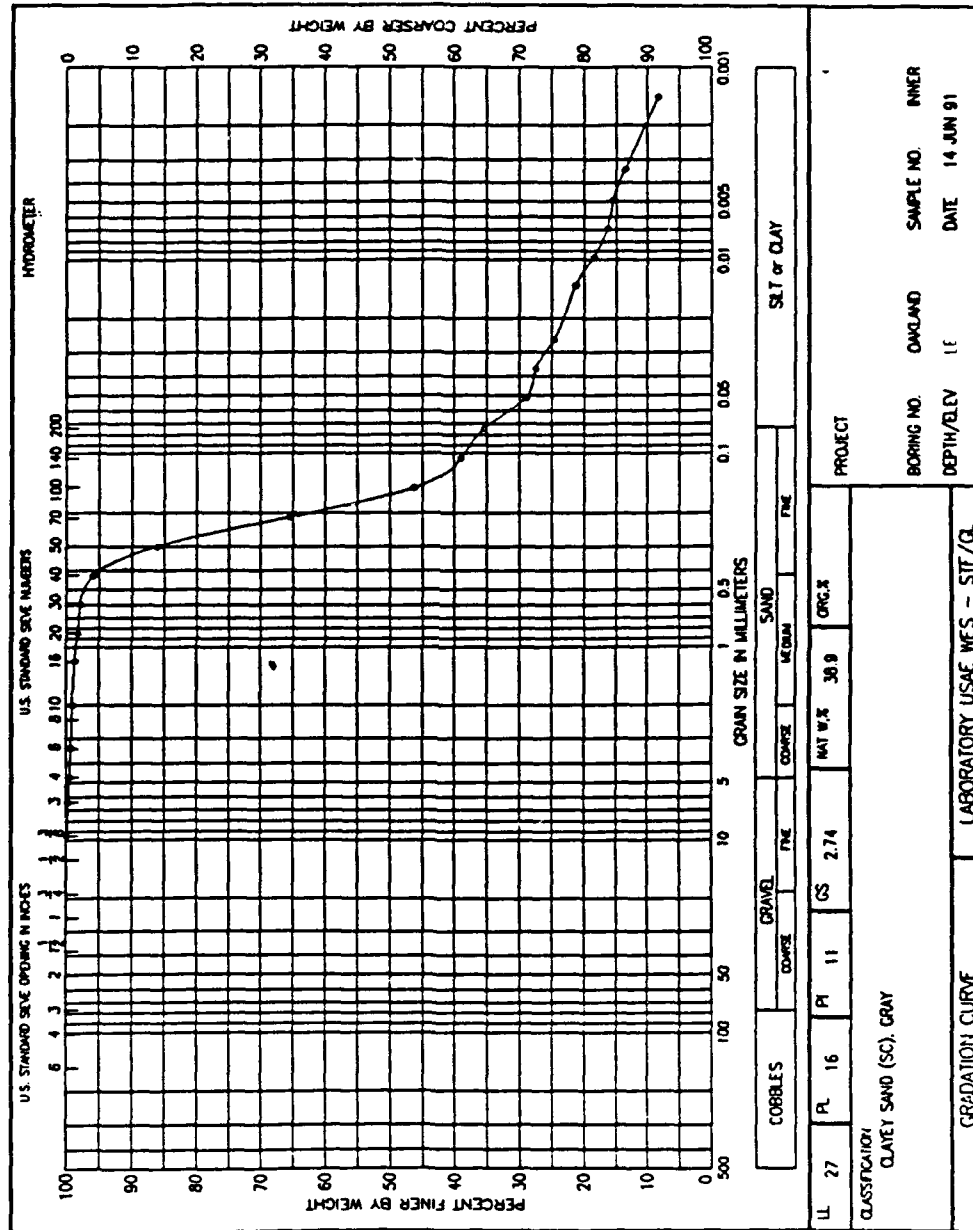


Figure II-13. Physical Engineering Properties of Oakland Inner Harbor Sediment (OH11)

Table II-1
Variability of Selected Sediment Quality Data After Mixing

<u>Sample No.</u>	<u>Copper mg/kg</u>	<u>TOC mg/kg</u>	<u>pH</u>	<u>% Silt & Clay</u>	<u>% Sand</u>
<u>Oakland Outer Harbor Sediment (OHO)</u>					
OOW-EL	27.7	6370	7.7	47	53
OOW-SR	22.4	5330	7.5	39	61
OOW-PL	24.9	5760	7.6	37	63
OOW-LE	25.1	5540	7.7	43	57
OOW-AC	25.9	7210	7.6	46	54
mean	25.2	6042	7.6	42	58
std. dev.	1.71	679.8	0.08	3.9	3.9
coeff. of var.	6.8	11.3	1.1	9.2	6.7
<u>Oakland Inner Harbor Sediment (OHI1)</u>					
OIW-EL	19.6	3640	7.4	34	66
OIW-SR	17.9	3230	7.2	33	67
OIW-PL	17.4	2660	7.4	35	65
OIW-LE	18.0	3720	7.3	33	67
OIW-AC	16.6	3570	7.4	31	69
mean	17.9	3364	7.3	33	67
std. dev.	0.98	389.6	0.09	1.3	1.3
coeff. of var.	5.5	11.6	1.2	4.0	2.0

Sediment and Soil Chemical characterization

Results of the chemical analyses of the Oakland sediments are shown in Tables II-2 and II-3 (metals), II-4 (butyltins), II-5 and II-6 (PAHs), and II-7 (pesticides). Oakland sediments were analyzed for PCBs and found to have values below detection limits (see Appendix A).

Bulk chemical analysis data for sediments provide only an inventory of the presence and concentrations of contaminants. These data can be compared to bulk chemical analysis data for potential disposal site sediments or soils,

Table II-2
Mean Concentrations of Metals in Oakland Harbor Sediments,
Twitchell Island Soil and Levee Soils

Parameter	Concentrations mg/kg dry weight			
	Oakland Inner (OH11)	Oakland Outer (OH0)	Twitchell Island*	Levee Soils*
Silver / Ag	0.110 (.014)**	0.203 (.015)	0.14	--
Arsenic / As	5.620 (1.21)	6.900 (.762)	14.7	9.3
Cadmium / Cd	0.148 (.021)	0.233 (.006)	0.46	3.4
Chromium / Cr	381.3 (55.0)	364.0 (21.4)	129.0	43.8
Copper / Cu	24.53 (1.65)	31.07 (1.27)	41.0	29.0
Mercury / Hg	0.110 (.026)	0.166 (.010)	0.21	0.214
Nickel / Ni	65.20 (2.60)	84.03 (3.46)	73.0	39.9
Lead / Pb	14.15 (1.38)	18.67 (1.07)	13.0	10.8
Selenium / Se	0.173 (.021)	0.267 (.035)	--	0.07
Zinc / Zn	61.10 (2.69)	84.80 (2.61)	96.0	59.3

* Data for Twitchell Island and Levee soils are from Lee et al. 1992.

** Values shown in parentheses are standard deviations of four samples.

and/or to available information or literature that give perspective and/or guidance on acceptable levels of contaminants in soils for specific uses. One example of guidance on acceptable levels of contaminants in soils for a specific use is the maximum allowable metal concentrations in sludge amended soils for agricultural crop production (Table II-8). Another example of bulk chemical analysis data that could be used for comparison is soil data from

Table II-3
Concentrations of Metals in a Standard Reference Material Analyzed
By the Analytical Laboratory - Battelle PN Laboratories

<u>Parameter</u>	<u>OW - S</u>	<u>SRM - Certified Value</u>
Silver / Ag	0.09	NA *
Arsenic / As	11.0	11.6
Cadmium / Cd	0.32	0.36
Chromium / Cr	68.0	76.0
Copper / Cu	20.1	18.0
Mercury / Hg	0.078	0.063
Nickel / Ni	34.3	32.0
Lead / Pb	26.8	28.2
Selenium / Se	0.54	(0.6) **
Zinc / Zn	131.3	138.0

* Not analyzed.

** Values in parentheses are not certified.

Twitchell Island, a potential disposal site for levee rehabilitation (Lee et al. 1992). These comparisons will indicate whether the dredged material contains concentrations of contaminants lower than, equal to, or higher than the respective referenced data and will indicate whether there is reason to believe the dredged material is contaminated and there is a need for further testing.

Metal concentrations in Oakland Inner and Oakland Outer sediments were compared to the Twitchell Island soil concentrations from previous evaluations in Table II-2. Most of these metals are not unusually elevated but chromium and lead in both Oakland Inner and Outer sediments were found to be higher than the chromium and lead at Twitchell Island and in the levee soils, also obtained from Twitchell Island.

The butyltin data (Table II-4) for Oakland sediments shows these compounds are present, but at concentrations of 11 ppb or lower. These concentrations are elevated in comparison to the Twitchell Island soils but are much less than the concentrations of butyltins found in the previous study (Lee et al. 1992) of Oakland Inner Harbor Turning Basin sediment. There are few specific guidelines for evaluating butyltins in sediments.

Table II-4
Mean Concentrations of Butyltins in Oakland Harbor Sediments
and Twitchell Island Soil

<u>Parameter</u>	<u>Concentrations mg/kg dry weight</u>			
	<u>Oakland Inner (OH11)</u>	<u>Oakland Outer (OHO)</u>	<u>Twitchell Island*</u>	<u>Levee Soils*</u>
Tetra	< 0.5	< 0.6	NA **	NA
Tri	5.07 (0.76)	2.87 (0.21)	< 2.0	NA
Di	4.53 (0.55)	2.50 (0.90)	< 2.0	NA
Mono	0.47 (0.12)	1.00 (0.63)	< 2.0	NA
TOTAL	10.57	6.97		

* Data for Twitchell Is. and Levee soils are from Lee et al. 1992.

** Values shown in parentheses are standard deviations.

† Not available.

The PAH data set (Table II-5) indicates that the Oakland Inner and Oakland Outer sediments contain lower concentrations of PAHs than Twitchell soils. The Twitchell Island data, however, are from Lee et al. (1992). The analyses were not conducted at the same time as the Oakland Inner and Outer Harbor sediments and detection limits appear to be higher for the Twitchell data. Tatem (1990) showed that many reference sediments do not contain detectible concentrations of PAHs and that the mean total PAHs of typical contaminated sediments is 25 ppm or 25,000 ppb, levels that are much greater than those found in these Oakland Harbor sediments. Table II-6 shows PAH method blank values for the data presented in Table II-5. Naphthalene and pyrene were the only PAHs that were detected in the method blanks.

Oakland Outer Harbor sediment contains the pesticide endosulfan sulfate and the Twitchell soil contains DDE and DDT (Table II-7) but the concentrations are in the low ppb range and should not be of concern at an upland disposal site. The PCB data are presented in Appendix A. All values are less than the detection limits that ranged from 27 ppb to 270 ppb.

Table II-5
Mean Concentrations of PAHs in Oakland Harbor Sediments
and Twitchell Island Soil

Parameter	Concentrations mg/kg dry weight		
	Oakland Inner (OHI)	Oakland Outer (OHO)	Twitchell Island*
Naphthalene	8.0	8.0	< 20
Acenaphthylene	3.3	3.3	< 20
Acenaphthene	5.0	4.0	< 20
Fluorene	3.0	4.0	< 20
Phenanthrene	24.3	23.7	50
Anthracene	7.0	8.3	< 20
Fluoranthene	71.0	50.0	260
Pyrene	123.3	84.0	320
Benzo(a)anthracene	41.7	40.0	70
Chrysene	45.0	50.3	120
Benzofluoranthene**	152.7	132.0	250
Benzo(a)pyrene	110.0	92.0	180
Indeno(1,2,3-c,d)pyrene	86.0	91.7	180
Dibenzo(a,h)anthracene	17.0	14.7	20
Benzo(g,h,i)perylene	109.7	119.7	210
TOTALS	807.0	725.7	1760
Mean % Sur Rec Anthracene	79.3	86.0	

* Data for Twitchell Island are from Lee et al. 1992.

** All benzofluoranthene isomers (b,j and k) are quantified together.

Table II-6
PAH Method Blank Values for Oakland Inner / Oakland
Outer Harbor Sediments

<u>Parameter</u>	<u>Concentrations (ug/kg, dry weight)</u>
Naphthalene	3.6
Acenaphthylene	<0.32
Acenaphthene	<0.80
Fluorene	<0.64
Phenanthrene	<0.87
Anthracene	<0.37
Fluoranthene	<0.53
Pyrene	0.58
Benzo(a)anthracene	<0.37
Chrysene	<0.32
Benzofluoranthene	<0.40
Benzo(a)pyrene	<0.32
Indeno(1,2,3-c,d)pyrene	<0.51
Dibenzo(a,h)anthracene	<0.29
Benzo(g,h,i)perylene	<0.25

Table II-7

Mean Concentrations of Pesticides in Oakland Harbor Sediments,
Twitchell Island Soil and Levee Soils

<u>Parameter</u>	<u>Concentrations mg/kg dry weight</u>				
	<u>Oakland Inner (OH1)</u>	<u>Oakland Outer (OH0)</u>	<u>Twitchell Island*</u>	<u>Levee Soils*</u>	<u>Method Blank</u>
Aldrin	< 3	< 3	< 1	NA **	< 2
A - BHC	< 3	< 3	< 1	NA	< 2
B - BHC	< 3	< 3	< 1	NA	< 2
D - BHC	< 3	< 3	< 1	NA	< 2
Chlordane	< 3	< 3	< 1	NA	< 2
4,4-DDD	< 3	< 3	< 3	NA	< 2
4,4-DDE	< 3	< 3	2.6	3.8	< 2
4,4-DDT	< 3	< 3	5.8	7.3	< 2
Dieldrin	< 3	< 3	< 1.5	NA	< 2
Endosulfan I	< 3	< 3	< 1	NA	< 2
Endosulfan II	< 3	3.3	< 1.5	NA	< 2
Endosulfan sulfate	< 3	20.3	< 3	NA	< 2
Endrin	< 3	< 3	< 1.5	NA	< 2
Endrin aldehyde	< 3	< 3	< 1.5	NA	< 2
Heptachlor	< 3	< 3	< 1	NA	< 2
Heptachlorepoxyde	< 3	< 3	< 1	NA	< 2
Lindane (g-BHC)	< 3	< 3	< 1	NA	< 2
Toxaphene	< 27	< 31	< 150	NA	< 20
Methoxychlor	< 5	< 6	< 4	NA	< 4
Endrin ketone	< 3	< 3	< 1.5	NA	< 2

* Data for Twitchell Island and Levee soils are from Lee et al. 1992.

** Not available.

Table II-8

Background Levels and Allowable Applications of Several Heavy Metals
for U.S. Cropland Soils *

<u>Parameter</u>	<u>Background Concentration in Surface Soils, mg/kg</u>			<u>No Effect Allowed Addition** kg/ha</u>	<u>Median Plus Allowed Application mg/kg</u>
	<u>5 Percentile</u>	<u>Median</u>	<u>95 Percentile</u>		
Lead	4.0	11	27	1,000	511
Zinc	7.3	54	129	500	304
Copper	3.7	19	96	250	144
Nickel	3.8	19	59	125	82
Cadmium	0.035	0.20	0.78	5	2.7
pH	4.6	6.1	8.1	--	--

* From Table C11, Lee et al. (1991).

** Allowed application is mixed into the 0- to 15-cm (0- to 6-in.) surface layer of soil.

PART III: EFFLUENT TEST

Chemical Evaluation

Methods and Materials

Applicability of test procedure. The prediction of effluent water quality from upland disposal sites is one of the evaluations described by Francingues et al. 1985 for the management of dredged material. The interpretation of the test data was generally described in the decision making framework of Peddicord et al. 1986 and Lee et al. 1991. The term effluent is normally used to describe the water discharged from a confined (diked) area during hydraulic placement of dredged material. Under these conditions a pond of water is maintained within the diked area, and the volumetric flow rate of effluent is approximately equal to the volumetric inflow rate.

For the disposal operation as described for the Oakland Harbor project, the conditions for "effluent" discharge are much different. First, the material will be mechanically dredged, transported to the disposal site by barge, removed directly from the barge with a clamshell, and placed in a confined disposal facility (CDF). These operations will result in minimal entrainment of excess water as compared to a hydraulic placement operation.

There is no standardized testing procedure for prediction of the quality of water discharged during placement of dredged material on land by mechanical equipment, as described above. However, modified elutriate procedures have been developed for prediction of the quality of effluent discharged from confined disposal areas during hydraulic placement (Palermo 1985). These tests are designed to estimate both dissolved and particle-associated contaminant concentrations in the effluent. The modified elutriate test is considered a conservative ("worst case") estimate of contaminant release for material placed by mechanical means, therefore, these procedures were used to estimate the quality of effluent discharged from the unconfined mechanical placement.

The use of modified elutriate procedures for this case is considered conservative ("worst case") for several reasons. The test procedures simulate the complete mixing of sediment and water during hydraulic dredging processes and would result in more potential contaminant release to water than would occur with mechanical dredging and placement. Also, the modified elutriate procedure calls for extraction of a sample for analysis after a settling period of 24 hours. Such a procedure would result in a higher concentration

of particle-associated contaminants than would be expected for water released from a mechanically placed material. This is due to only the finer particle fractions remaining after a 24- hour settling period. However, for mechanical effluent, some or all particle fractions would be "washed" from the sediment mass during the water loss process.

Procedures. Modified elutriate tests were conducted (Figure III-1) on composite samples of Oakland Outer and Inner Harbor sediments using procedures described in Palermo (1985). All elutriate tests were conducted in triplicate using the composite sediment samples and dredging site water samples. The elutriate test procedures and analysis of physicochemical parameters in the elutriate such as total suspended solids (TSS), pH, dissolved oxygen (DO), and salinity were conducted by Dr. Henry Tatem (EPED). Subsamples of the elutriate were processed, filtered, preserved, and transported to Battelle for chemical analysis of metals and tri-, di-, and mono-butyltins, pesticides, PAHs and PCBs. Because of the need for large samples for analysis, TSS concentrations were not determined for the elutriate samples used for chemical analysis, but were determined using separate elutriate test runs.

Data were analyzed using the computer program EFQUAL which is designed for reduction and analysis of modified elutriate data and prediction of effluent quality from confined disposal areas. EFQUAL calculates predicted values for both dissolved and total effluent contaminant concentrations and determines required effluent dilutions for those parameters exceeding given criteria or standards. EFQUAL is a part of the Automated Dredging and Disposal Alternatives Management System (Schroeder and Palermo 1990).

Results and Discussion

The replicate mean results for dissolved contaminants in the modified elutriate tests are summarized in Tables III-1 and III-2 for the Inner and Outer composites, respectively. For those replicates for which the elutriate samples were below detection, the detection limit was used in calculating the mean values.

The dissolved and total modified elutriate concentrations were used to calculate fractions of the contaminants associated with the suspended particles as described in Palermo (1985). These fractions were then used to estimate a total concentration of contaminants in the effluent for a range of assumed effluent TSS concentrations from 50 to 200 mg/l. These results are shown in Tables III-3 and III-4 for the Inner and Outer composites, respectively. The total modified elutriate concentrations were equal to or lower

Table III-1
Modified Elutriate Results for Inner Composite Sample

Parameter	Mean Elutriate Dissolved ug/l	CA State* RWQCB Limitations ug/l	Freshwater** EPA Acute WQ Criteria ug/l	Saltwater** EPA Acute WQ Criteria ug/l
Silver	0.0267		4.1	2.3
Arsenic	3.11			
Cadmium	0.2173	1.8	3.9	43
Chromium	0.79	16	16	1100
Copper	4.65	9.2	18	2.9
Mercury	0.0407	2.4	2.4	2.1
Nickel	4.66		1400	75
Lead	3.55	34	82	140
Selenium	bd		260	410
Zinc	34.4	65	120	95
Tributyltin	0.24	0.08		
Dibutyltin	0.0258			
Monobutyltin	0.0164			
Conductivity	--			
pH	7.6			
DO	5.9-7.4			
Salinity	28			
TSS				
Naphthalene	0.007		2300	2350
Acenaphthylene	bd			
Acenaphthene	bd		1700	970
Fluorene	bd		0	0
Phenanthrene	bd			
Anthracene	0.0354			
Fluoranthene	0.0136		3980	40
Pyrene	0.031			
Benzo[a]anthracene	bd			
Chrysene	bd			
Benzo[k]fluoranthene	bd			
Benzo[b]fluoranthene	0.019			
Benzo[a]pyrene	bd			
Indeno[1,2,3-c,d]pyrene	bd			
Dibenzo[a,h]anthracene	bd			
Benzo[g,h,i]perylene	0.0085			

* CA state limitations are those issued for the Twitchell Island project (CRWQCB 1989).

** In the absence of State Water Quality Standards for an undetermined disposal site, it was assumed that the Federal Water Quality criteria would apply.



Figure III-1. Glass Columns of Sediment/Water Elutriate Mixture

than concentrations for the dissolved samples for some test replicates. In this case, the TSS fraction did not contribute to the total concentrations.

Water quality standards. The estimated dissolved concentrations in the effluent are equal to the dissolved modified elutriate test concentrations as shown in Tables III-1 and III-2. For this analysis, the dissolved effluent concentrations were compared to the assumed EPA Fresh and Marine Acute Water Quality Criteria for the Protection of Aquatic Life (EPA 1987), and the assumed Effluent and Receiving Water Limitation Standards for the disposal of Oakland Harbor dredged material issued by CRWQCB in response to a permit application by the Port of Oakland.

EFQUAL uses t-tests to compare the predicted effluent concentrations to specified criteria or standards. Contaminant concentrations less than or equal to the criteria are postulated as the null hypothesis. Contaminant concentrations greater than the criteria serve as the alternate hypothesis. A rejection of the null hypothesis suggests values were greater than the criteria. In general, the predicted dissolved effluent concentrations were well below all assumed criteria and standards. For the Inner sediment, copper exceeded the assumed EPA saltwater criterion (level of confidence of 86%),

Table III-2
Modified Elutriate Results for Outer Composite Sample

Parameter	Mean Elutriate Dissolved ug/l	CA State* RWQCB Limitations ug/l	Freshwater** EPA Acute WQ Criteria ug/l	Saltwater** EPA Acute WQ Criteria ug/l
Silver	0.01		4.1	2.3
Arsenic	3.18			
Cadmium	0.2867	1.8	3.9	43
Chromium	0.45	16	16	1100
Copper	33.6	9.2	18	2.9
Mercury	0.0067	2.4	2.4	2.1
Nickel	4.21		1400	75
Lead	2.98	34	82	140
Selenium	bd		260	410
Zinc	45.9	65	120	95
Tributyltin	0.0107	0.08		
Dibutyltin	0.0329			
Monobutyltin	0.0113			
Conductivity	--			
pH	7.5			
DO	9			
Salinity	26			
TSS				
Naphthalene	0.1155		2300	2350
Acenaphthylene	0.0176			
Acenaphthene	0.0439		1700	970
Fluorene	0.0351		0	0
Phenanthrene	0.0468			
Anthracene	0.0205			
Fluoranthene	0.0292		3980	40
Pyrene	0.022			
Benzo[a]anthracene	0.0205			
Chrysene	0.0176			
Benzo[k]fluoranthene	0.022			
Benzo[b]fluoranthene	0.022			
Benzo[a]pyrene	0.0176			
Indeno[1,2,3-c,d]pyrene	0.0278			
Dibenzo[a,h]anthracene	0.0161			
Benzo[g,h,i]perylene	0.014			

* CA state limitations are those issued for the Twitchell Island project (CRWQCB 1989).

** In the absence of State Water Quality Standards for an undetermined disposal site, it was assumed that the Federal Water Quality criteria would apply.

Table III-3

Predicted Effluent Total Concentrations for Inner Sediment

<u>Parameter</u>	<u>Predicted Total Effluent Concentrations in ug/l for Effluent TSS Concentration</u>			
	<u>50 mg/l</u>	<u>100 mg/l</u>	<u>150 mg/l</u>	<u>200 mg/l</u>
Silver	0.0267	0.027	0.027	0.027
Arsenic	3.4200	3.726	4.032	4.339
Cadmium	0.2173	0.2173	0.2173	0.2173
Chromium	1.2483	1.7066	2.1600	2.6200
Copper	4.7000	4.7576	4.810	4.869
Mercury	0.0494	0.058	0.0668	0.0754
Nickel	5.0613	5.4592	5.8572	6.2552
Lead	3.870	4.196	4.520	4.840
Selenium	bd*	bd*	bd*	bd*
Zinc	37.656	40.910	44.169	47.425
Tributyltin	0.24	0.24	0.24	0.24
Dibutyltin	0.0392	0.0525	0.0659	0.0792
Monobutyltin	0.017	0.0176	0.0181	0.0187
Naphthalene	0.0113	0.0154	0.0196	0.0237
Acenaphthylene	0	0	0	0
Acenaphthene	0.0192	0.384	0.0575	0.0767
Fluorene	0	0	0	0
Phenanthrene	0.0017	0.0034	0.0051	0.0068
Anthracene	0.0354	0.0354	0.0354	0.0354
Fluoranthene	0.0151	0.0166	0.0182	0.0197
Pyrene	0.0422	0.0534	0.0645	0.0757
Benzo[a]anthracene	0.0134	0.0268	0.0402	0.0535
Chrysene	0.0033	0.0067	0.01	0.0133
Benzo[k]fluoranthene	0.0044	0.0089	0.0134	0.0178
Benzo[b]fluoranthene	0.02	0.0209	0.0219	0.0229
Benzo[a]pyrene	0.0069	0.0138	0.0207	0.0257
Indeno[1,2,3-c,d]pyrene	0.0067	0.0133	0.02	0.0266
Dibenzo[a,h]anthracene	0	0	0	0
Benzo[g,h,i]perylene	0.0112	0.0139	0.0166	0.0194

* bd - below detection limit.

Table III-4
Predicted Effluent Total Concentrations for Outer Sediment

Parameter	Predicted Total Effluent Concentrations in ug/l for Effluent TSS Concentration			
	50 mg/l	100 mg/l	150 mg/l	200 mg/l
Silver	0.0258	0.042	0.057	0.073
Arsenic	3.9867	4.790	5.590	6.397
Cadmium	0.3088	0.3308	0.3529	0.3749
Chromium	1.7197	2.9894	4.2591	5.5288
Copper	33.6000	33.6000	33.600	33.600
Mercury	0.0149	0.023	0.0313	0.0395
Nickel	5.62	7.04	8.45	9.87
Lead	2.980	2.980	2.980	2.980
Selenium	bd	bd	bd	bd
Zinc	47.000	48.100	48.208	50.311
Tributyltin	0.0115	0.0122	0.013	0.0137
Dibutyltin	0.0329	0.0329	0.0329	0.0329
Monobutyltin	0.0113	0.0113	0.0113	0.0113
Naphthalene	0.1162	0.1169	0.1176	0.1183
Acenaphthylene	0.0177	0.0178	0.0179	0.018
Acenaphthene	0.0442	0.0444	0.0447	0.0449
Fluorene	0.0353	0.0355	0.0357	0.0359
Phenanthrene	0.0474	0.048	0.0487	0.0493
Anthracene	0.0206	0.0207	0.0208	0.0209
Fluoranthene	0.0294	0.0296	0.0298	0.03
Pyrene	0.0240	0.0259	0.0279	0.0298
Benzo[a]anthracene	0.0206	0.0207	0.0208	0.0209
Chrysene	0.0177	0.0178	0.0179	0.018
Benzo[k]fluoranthene	0.0221	0.0223	0.0224	0.0225
Benzo[b]fluoranthene	0.0221	0.0223	0.0224	0.0225
Benzo[a]pyrene	0.0177	0.0178	0.0179	0.018
Indeno[1,2,3-c,d]pyrene	0.0279	0.0280	0.0282	0.0283
Dibenzo[a,h]anthracene	0.0162	0.0163	0.0164	0.0165
Benzo[g,h,i]perylene	0.0141	0.0142	0.0143	0.0144

however the background concentration was also above the criterion and was higher than the predicted effluent concentration.

For the Inner sediment, tributyltin exceeded the assumed CRWQCB limitation standard (level of confidence 76%), and a dilution in the mixing zone of less than 2 would be required to meet a standard. For the Outer sediment, copper exceeded all of the assumed criteria and standards, however, the laboratory results for dissolved elutriate concentrations were significantly

higher than the corresponding total concentrations. This indicates a possible analytical error. Assuming the dissolved concentrations were as predicted, dilutions of 21, 2, and 31 would be required to meet the assumed CRWQCB limitation standard, the assumed EPA Freshwater criterion, and the assumed EPA saltwater criterion, respectively.

Mass release. No standards for mass loading were specified by the Regional Water Quality Control Board. Therefore, predictions of the total concentration of contaminants in the effluent for an assumed range of effluent TSS from 50 to 200 mg/L were used to estimate potential mass releases. These results are shown in Tables III-3 and III-4. These estimates of total concentrations were used to compute a mass release of contaminants expressed as a percentage for an assumed hydraulic placement operation.

The sediment contaminant concentrations for the inner and outer composite samples were used as the initial contaminant concentrations as placed (shown in Tables III-5 and III-6). Hydraulic placement was assumed to result in an inflow suspended solids concentration of 150 g/l. The total effluent concentrations of contaminants for the assumed range of 50 to 200 mg/L of effluent TSS was then used to compute the percentage of total contaminants placed which would be discharged as effluent. Mass release calculated for the hydraulic placement method is conservative as compared with that for mechanical placement. The resulting mass releases expressed as percentages of the total contaminants placed are summarized in Tables III-5 and III-6.

The mass releases were generally well below one percent. The butyltin releases for both the inner and outer harbor sediments were higher ranging up to 28 percent. These higher values of release expressed as a percentage reflect the fact the initial concentrations of butyltins in the sediments were comparatively low and all release is associated with the dissolved fraction. These data generally indicate that the placement operation should be managed to reduce the level of suspended solids in the effluent to the greatest degree practical and very little soluble butyltins will be discharged.

Effluent Impacts and Control

The evaluation of the effluent indicates that, with the exception of copper and tributyltin, the dissolved concentrations of all contaminants discharged as effluent will meet all assumed water quality criteria and standards prior to any mixing. The concentrations of dissolved contaminants potentially exceeding assumed criteria will require a dilution of up to 2 for Oakland Inner Harbor sediment and 31 for Oakland Outer Harbor sediment in the mixing

Table III-5
Estimated Mass Release for Inner Sediment

Parameter	Sediment Concentration mg/kg	Predicted Total Effluent Concentrations in ug/l for Effluent			
		TSS Concentration			
		50 mg/l	100 mg/l	150 mg/l	200 mg/l
Silver	0.11	0.16	0.16	0.16	0.16
Arsenic	5.62	0.41	0.44	0.48	0.51
Cadmium	0.15	0.97	0.97	0.97	0.97
Chromium	381	0.00	0.00	0.00	0.00
Copper	24.5	0.13	0.13	0.13	0.13
Mercury	0.109	0.30	0.35	0.41	0.46
Nickel	65.2	0.05	0.06	0.06	0.06
Lead	14.2	0.18	0.20	0.21	0.23
Selenium	0.17	0.00	0.00	0.00	0.00
Zinc	61.1	0.41	0.45	0.48	0.52
Tributyltin	0.0057	28.07	28.07	28.07	28.07
Dibutyltin	0.0045	5.81	7.78	9.76	11.73
Monobutyltin	0.00047	24.11	24.96	25.67	26.52
Naphthalene	0.008	0.94	1.28	1.63	1.98
Acenaphthylene	0.0033	0.00	0.00	0.00	0.00
Acenaphthene	0.005	2.56	51.20	7.67	10.23
Fluorene	0.003	0.00	0.00	0.00	0.00
Phenanthrene	0.0243	0.05	0.09	0.14	0.19
Anthracene	0.007	3.37	3.37	3.37	3.37
Fluoranthene	0.071	0.14	0.16	0.17	0.18
Pyrene	0.1233	0.23	0.29	0.35	0.41
Benzo[a]anthracene	0.0417	0.21	0.43	0.64	0.86
Chrysene	0.045	0.05	0.10	0.15	0.20
Benzo[k]fluoranthene	0.1527	0.02	0.04	0.06	0.08
Benzo[b]fluoranthene	0.1527	0.09	0.09	0.10	0.10
Benzo[a]pyrene	0.11	0.04	0.08	0.13	0.16
Indeno[1,2,3-c,d]pyrene	0.086	0.05	0.10	0.16	0.21
Dibenzo[a,h]anthracene	0.017	0.00	0.00	0.00	0.00
Benzo[g,h,i]perylene	0.1097	0.07	0.08	0.10	0.12

Table III-6
Estimated Mass Release for Outer Sediment

Parameter	Sediment Concentration mg/kg	Predicted Total Effluent Concentrations in ug/l for Effluent TSS Concentration			
		50	100	150	200
		mg/l	mg/l	mg/l	mg/l
Silver	0.2	0.09	0.14	0.19	0.24
Arsenic	6.4	0.42	0.50	0.58	0.67
Cadmium	0.23	0.90	0.96	1.02	1.09
Chromium	364	0.00	0.01	0.01	0.01
Copper	31.1	0.72	0.72	0.72	0.72
Mercury	0.166	0.06	0.09	0.13	0.16
Nickel	84	0.04	0.06	0.07	0.08
Lead	18.7	0.11	0.11	0.11	0.11
Selenium	26.7	0.00	0.00	0.00	0.00
Zinc	84.8	0.37	0.38	0.38	0.40
Tributyltin	0.00287	2.67	2.83	3.02	3.18
Dibutyltin	0.0025	8.77	8.77	8.77	8.77
Monobutyltin	0.001	7.53	7.53	7.53	7.53
Naphthalene	0.008	9.68	9.74	9.80	9.86
Acenaphthylene	0.0033	3.58	3.60	3.62	3.64
Acenaphthene	0.004	7.37	7.40	7.45	7.48
Fluorene	0.004	5.88	5.92	5.95	5.98
Phenanthrene	0.0237	1.33	1.35	1.37	1.39
Anthracene	0.0083	1.65	1.66	1.67	1.68
Fluoranthene	0.05	0.39	0.39	0.40	0.40
Pyrene	0.084	0.19	0.21	0.22	0.24
Benzo[a]anthracene	0.04	0.34	0.35	0.35	0.35
Chrysene	0.0503	0.23	0.24	0.24	0.24
Benzo[k]fluoranthene	0.132	0.11	0.11	0.11	0.11
Benzo[b]fluoranthene	0.132	0.11	0.11	0.11	0.11
Benzo[a]pyrene	0.092	0.13	0.13	0.13	0.13
Indeno[1,2,3-c,d]pyrene	0.0917	0.20	0.20	0.21	0.21
Dibenzo[a,h]anthracene	0.0147	0.73	0.74	0.74	0.75
Benzo[g,h,i]perylene	0.1197	0.08	0.08	0.08	0.08

zone to meet the assumed criteria and standards. This degree of mixing can generally be achieved within a short distance of the effluent discharge.

The total mass release of contaminants as effluent was estimated to be generally less than one percent of the total contaminants placed, and varied with respect to the assumed concentration of TSS in the effluent. The placement operation should be managed to reduce the TSS concentration in the effluent to the largest degree practical. This can be accomplished by ponding of effluent water within the toe dikes prior to discharge. The resulting sedimentation of suspended solids should reduce the total mass release of contaminants.

The salinity of the effluent could potentially cause some adverse environmental impacts. A mixing zone with a dilution of approximately 10 to 1 will be required to reduce the salinity to less than 2 ppt and will minimize any impacts due salinity.

Biological Evaluation

Methods and Materials

Background. The modified elutriate test procedure is discussed by Palermo (1986). It is used to predict both dissolved and particle-associated concentrations of environmental contaminants in effluents from confined dredged material disposal areas. Biological evaluation of a modified elutriate is the second method described by Lee et al. 1991 to evaluate the impact of discharges from confined disposal facilities (CDF).

Procedures. Modified elutriates were prepared following procedures outlined in Palermo (1985) and (1986). Step one was to determine the grams of dry Oakland Inner or Oakland Outer sediment in a known volume (grams per liter). This value was then used in the equations described in Palermo (1985), assuming a slurry concentration of 150 grams per liter. Sediment and site water were well mixed in a gallon jar prior to being agitated vigorously in a 4-liter cylinder for 1 hour by aeration. After being allowed to settle for 24 hours the supernatant was extracted from the cylinder by siphoning. A large volume of elutriate was needed for the chemical analyses, both filtered and unfiltered samples, and the bioassays. Each cylinder produced approximately 1.8 to 2.2 liters of modified elutriate. Samples of the modified elutriate were sent for chemical analyses of metals, butyltins and PAHs. The chemistry laboratory required as much as 3 liters of samples (6 liters

counting both filtered and unfiltered samples) for each of the two organic parameters and about 1 liter for the metals. The procedure for preparation of the samples for chemical analysis was to take the contents of two or three cylinders to make one chemical sample, both filtered and unfiltered. Additional modified elutriate tests were conducted for the bioassay testing. For the bioassay tests, approximately 12 liters of water were siphoned from the 5 cylinders and placed in gallon jars. In some cases the modified elutriates were held overnight, at 4 °C, while beakers and animals were being prepared; there was no sediment layer present in these samples. The bioassays were performed on composite samples of modified elutriate from all five cylinders. Separate modified elutriates were made, using similar sediment/water concentrations, for the total suspended solids determinations.

Results and Discussion

Tables III-7 to III-12 present data from the various modified elutriate bioassays. These modified elutriates were always at a salinity of 26 to 28 ppt because they were made with dredging site water. The modified elutriates settled to 3 distinct layers, a 2-3 cm sandy layer, a lighter 12 cm sediment layer and the relatively clear water layer. The 50% Oakland Outer modified elutriate was 12 ppt salinity; the 10% modified elutriate was 2 ppt. Dissolved oxygen of the modified elutriates was always greater than 7 to 8 ppm; pH was 7.7 to 7.9, similar to laboratory culture water of the same salinity.

Table III-7 presents data for *Daphnia* and Oakland Inner Harbor sediment modified elutriate. Survival of animals exposed to the 10 % modified elutriate was comparable to the controls indicating no toxicity. Animals exposed to the 50 % elutriate concentration were affected by the salinity as shown by the results with 12-ppt controls. These test animals are normally found in either freshwater or low salinity brackish water and generally cannot survive at salinities greater than 5 to 7 ppt. *Neomysis* was exposed to these modified elutriates at two salinities, 12 and 25 ppt, and clearly demonstrated no toxicity associated with the Oakland Inner Harbor sediments. *Daphnia* and *Neomysis* were also exposed to modified elutriates prepared with Oakland Outer Harbor sediment. These data (Tables III-10 and III-11) also indicate no toxicity associated with exposure of these sensitive test organisms to the Oakland Outer Harbor sediment modified elutriates; again, salinity was the factor effecting *Daphnia* as described above for Table III-7.

Table III-7

Percent Survival of Daphnia Exposed to Oakland Inner Harbor Sediment
Modified Elutriate for 96 Hours at Two Salinities

<u>Treatment</u>	<u>Replicate</u>	<u>% Survival</u>	<u>Treatment</u>	<u>Replicate</u>	<u>% Survival</u>
			<u>3 ppt</u>		
Control	1	80	0 %	1	70
	2	100		2	80
	3	100		3	80
	4	90		4	100
	5	80		5	100
			<u>12 ppt</u>		
Controls	1	0	50 %	1	0
	2	0		2	0
	3	0		3	0
	4	0		4	0
	5	0		5	0

Table III-8

Percent Survival of Neomysis Exposed to Oakland Inner Harbor Sediment
Modified Elutriate for 96 Hours at 12-ppt Salinity

<u>Treatment</u>	<u>Replicate</u>	<u>Percent Survival</u>
Control	1	70
	2	80
	3	100
	4	100
	5	100
10 %	1	100
	2	80
	3	50
	4	100
	5	70
50 %	1	100
	2	80
	3	80
	4	100
	5	100

The 100% treatment was not conducted because the salinity of the Oakland Inner Harbor sediment modified elutriate was 25 ppt; the 100% concentration was tested during the 25-ppt mysid bioassay.

Table III-9

Percent Survival of Neomysis Exposed to Oakland Inner Harbor Sediment
Modified Elutriate for 96 Hours at 25-ppt Salinity

<u>Treatment</u>	<u>Replicate</u>	<u>Percent Survival</u>
Control	1	100
	2	90
	3	100
	4	100
	5	100
10 %	1	100
	2	80
	3	90
	4	100
	5	90
50 %	1	100
	2	90
	3	80
	4	100
	5	100
100 %	1	80
	2	90
	3	100
	4	90
	5	80
Site Water	1	100
	2	80
	3	100
	4	100
	5	100

Table III-10

Percent Survival of Daphnia Exposed to Oakland Outer Harbor Sediment
Modified Elutriate for 96 Hours at Various Salinities

<u>Salinity</u>	<u>Treatment</u>	<u>Replicate</u>	<u>Percent Survival</u>
0 ppt	Control	1	100
		2	100
		3	100
		4	100
		5	90
2 ppt	10 ‰	1	90
		2	100
		3	100
		4	90
		5	100
12 ppt	50 ‰	1	0
		2	0
		3	0
		4	0
		5	0

Table III-11
Percent Survival of Neomysis Exposed to Oakland Outer Harbor Sediment
Modified Elutriate for 96 Hours at 25-ppt Salinity

<u>Treatment</u>	<u>Replicate</u>	<u>Percent Survival</u>
Control	1	100
	2	100
	3	100
	4	100
	5	100
10 %	1	100
	2	100
	3	100
	4	100
	5	100
50 %	1	100
	2	100
	3	100
	4	100
	5	100
100 %	1	100
	2	100
	3	100
	4	100
	5	100
Site Water	1	100
	2	100
	3	100
	4	100
	5	100

PART IV: SURFACE RUNOFF TEST

Chemical Evaluation

Methods and Materials

Background. Sediments removed from waterways by construction projects sometimes contain elevated concentrations of contaminants such as heavy metals, polychlorinated biphenyls (PCBs), and polynuclear aromatic hydrocarbons (PAHs). The potential for adverse environmental impacts from contaminants carried by surface runoff depends on several factors including the chemical form of the contaminants and the type of disposal environment. Wet, unoxidized dredged material usually has a $\text{pH} \geq 7$ with most contaminants tightly bound to the sediment particulates. Movement of contaminants from the disposal site by surface runoff would result primarily from erosion of sediment (Skogerboe et al. 1987). Suspended solids concentrations in surface runoff could range from 5,000 to 50,000 mg/l. Unfiltered (total) contaminant concentrations in surface runoff could also be very high, while filtered (dissolved) contaminant concentrations would be relatively low. When the dredged material is placed in an upland disposal environment, physicochemical changes occur as the material dries and oxidizes. These changes may greatly affect the surface runoff water quality, particularly the filtered contaminant concentrations. As the sediment dries and oxidizes, a hard surface crust forms which makes the sediment more resistant to erosion and decreases suspended solids to 10 to 1,000 mg/l. Unfiltered contaminant concentrations will decrease by several orders of magnitude, but filtered concentrations of some contaminants may increase. When the filtered concentration statistically equals the unfiltered concentration, most of the contaminant is dissolved rather than adsorbed to particulates (Skogerboe et al. 1987).

The prediction of surface runoff water quality from Corps of Engineers (CE) upland disposal sites is one of the evaluations described by Francingues et al. (1985) for the management of dredged material. The interpretation of the test data has been generally described in the decision making framework of Peddicord et al. (1986) and Lee et al. (1991). The U.S. Army Engineer Waterways Experiment Station (WES) developed a rainfall simulator, lysimeter system to predict surface runoff water quality from CE project sites. The WES system is a rotating disk type rainfall simulator modified from a design of Morin, Goldberg, and Seginer (1967). It incorporates the latest methods to

accurately duplicate the drop size and terminal velocities of natural rainfall, factors which are critical in erosion and infiltration studies (Westerdahl and Skogerboe 1982). Extensive field verification studies have been conducted with the WES Rainfall Simulator, Lysimeter System on a wide range of CE project sites (Westerdahl and Skogerboe 1982; Lee and Skogerboe 1984; Skogerboe et al. 1987). The WES Rainfall Simulator/ Lysimeter System proved to be an effective tool for predicting surface runoff rates, soil loss, and runoff contaminant concentrations. This study was designed to predict potential surface runoff water quality from upland disposal of dredged material contaminated with heavy metals, PAHs, and tributyltin from the Oakland Harbor. Sediment was collected from Oakland Inner and Outer Harbors, and tested using the WES Rainfall Simulator/ Lysimeter System. Surface runoff water quality tests were conducted on the wet, unoxidized sediment and again, six months later on air-dried and oxidized sediment. Runoff samples were analyzed for suspended solids, pH, conductivity, and contaminants.

Test results were compared to the EPA Acute Water Quality Criteria for the Protection of Aquatic Life (USEPA 1987), and the Effluent and Receiving Water Limitation Standards for Waste Discharge issued by the California Regional Water Quality Control Board (CRWQCB 1989) in response to a permit application by the Port of Oakland for the disposal of Oakland Harbor sediment as levee building material at Twitchell Island in the Sacramento River Delta. In the absence of State Water Quality Standards for an undetermined disposal site, the Federal Water Quality criteria were assumed to be applicable to give some perspective to test results. Section 401 requires compliance with State Water Quality standards, rather than Federal Water Quality criteria. Final effluent limitations will be determined based on the local water quality objectives applicable to the area where the sediment is placed. These laboratory tests give predictions of water quality for specific conditions and should be considered an indication of the potential of an effluent, surface runoff or leachate to meet or exceed applicable water quality standards.

Surface runoff tests. Two lysimeters (4.57 m by 1.22 m) were filled to a depth of 0.33 m with sediment from either Oakland Inner or Outer Harbors. After thorough mixing, standing water on the sediment was decanted off the surface of each lysimeter. A composite sediment sample was collected from each lysimeter and analyzed for pH, electrical conductivity, arsenic, cadmium, chromium, copper, lead, mercury, zinc, tributyltin, dibutyltin, and monobutyltin, pesticides, PAHs and PCBs (USEPA 1986). Each sediment was then tested

with the WES rainfall simulator using three, 30-min storm events at 5.08-cm/hr on successive days (Figures IV-1, IV-2, IV-3), (Skogerboe et al. 1987). Run-off rates were measured every minute, and 4-liter samples were collected for chemical analysis at 5, 15, and 25 min after the runoff began to occur. Additional samples were collected for suspended solids determinations at several additional points along the surface runoff hydrograph. The 4-liter samples were combined into a composite sample for each test run and analyzed for filtered and unfiltered heavy metals, butyltins, pesticides, PAHs and PCBs (USEPA 1984).

The lysimeters were then covered with semi-transparent tops which allowed air movement over the surface of the sediment (Figure II-9). After 6 months of drying and oxidation (Figure IV-4), each sediment was sampled and three storm events were conducted on each lysimeter. Storm events, sample collection and sample analysis were the same as the wet stage tests.

One tailed t-tests were used to compare total and filtered surface runoff concentrations to the assumed EPA Fresh and Marine Acute Water Quality Criteria for the Protection of Aquatic Life (USEPA 1987), and the assumed Effluent and Receiving Water Limitation Standards for dredging Oakland Harbor issued by CRWQCB (Table IV-1) to the Port of Oakland. Contaminant concentrations less than or equal to the criteria or standards were postulated as the null hypothesis. Contaminant concentrations greater than the assumed EPA Criteria or CRWQCB standards served as the alternate hypothesis. A rejection of the null hypothesis indicated that values were greater than the assumed criteria or standards.

Statistical procedures were used to compare filtered (soluble) and unfiltered (total) contaminant concentrations in surface runoff from both sediments. The statistical tests were conducted using SAS Analysis of Variance (ANOVA) procedure (Barr et al. 1976). The null hypothesis was that all concentrations for a particular contaminant were equal. The alternate hypothesis was that at least two contaminant concentrations were not equal. Actual contaminant concentrations that were statistically different were determined using the SAS, Waller-Duncan Mean Separation Technique. All statistical tests were conducted at the $P = 0.05$ level of significance. A detailed description of the tests was given by Winer (1971).

Table IV-1

Water Quality Criteria and Standards for Comparison to Test Results

<u>Parameter</u>	<u>USEPA* Marine Acute Criteria</u>	<u>USEPA* Fresh Acute Criteria</u>	<u>Effluent** Limitation Standards</u>	<u>Receiving Water** Limitation Standards</u>
Arsenic	69	360	50	1
Cadmium	43	3.9	1.8	0.65
Chromium	1100	16	16	11
Copper	2.9	18	9.2	6.5
Mercury	2.1	2.4	2.4	0.012
Lead	140	82	34	--
Zinc	95	120	65	59
Tributyltin	--	--	0.080	0.020
Dibutyltin	--	--	--	--
Monobutyltin	--	--	--	--
Total butyltin	--	--	--	--

* In the absence of State Water Quality Criteria for an undetermined disposal site, it was assumed that the Federal Water Quality criteria would apply.

** Limitation standards issued by California Regional Water Quality Control Board in response to a permit application by the Port of Oakland (CRWQCB 1989) for disposal at Twitchell Island.



Figure IV-1. Rainfall Simulation on Anaerobic Oakland Harbor Sediment

Results

Wet, unoxidized surface runoff tests. Suspended solids concentrations were 4447 mg/L in surface runoff from the wet, unoxidized Inner Harbor sediment and 4610 mg/L from the Outer Harbor sediment (Table IV-2). These suspended solids concentrations were not statistically different due to large variability that normally occurs during this stage of the aging process. Surface runoff pH was 7.96 and 8.11 from the two sediments and conductivity was 0.99 and 1.55 mV/cm.

Results of the runoff tests showed that heavy metals in surface runoff from both the Inner and Outer Harbor sediments were mostly insoluble. Concentrations of filtered (soluble) metals were statistically less than unfiltered (total) concentrations (Table IV-3) except for arsenic, silver, and mercury. Concentrations of heavy metals were compared to the EPA Fresh and Marine Acute Maximum Criteria for the Protection of Marine Aquatic Life, and to the Effluent and Receiving Water Limitation Standards issued by CRWQCB for the Port of Oakland's permit application (Table IV-1). Most of the parameters determined in surface runoff unfiltered samples were statistically greater than at least one of the criteria or standards and several were statistically greater than all of the criteria and standards. However, only arsenic and copper concentrations were statistically greater than one criterion for filtered runoff samples from the Inner Harbor sediment. Arsenic was the only parameter in surface runoff from the Outer Harbor sediment that exceeded any of the criteria or standards.



Figure IV-2. Runoff Rate Measurements Were Taken Throughout the Rainfall Simulation

Concentrations of butyltins were not statistically higher in unfiltered runoff samples from either the Inner or Outer Harbor sediments compared to the filtered samples (Table IV-3). Water quality criteria were available only for tributyltin, and only the unfiltered runoff samples from the Inner Harbor sediment were statistically greater than the receiving water standards.

Dry, oxidized surface runoff tests. Concentrations of suspended solids in runoff samples from the dry, oxidized tests were statistically less than concentrations in samples from the wet, unoxidized tests (Table IV-2). The runoff pH of samples from the dry, oxidized tests were statistically less than samples from the wet, unoxidized tests but was still greater than 7.0 for the Outer Harbor sediment. Electrical conductivity in samples from the dry, oxidized tests were not statistically different than in samples from the wet, unoxidized tests.

Unfiltered heavy metal concentrations in runoff from the dry, oxidized sediments were mostly less than concentrations from the wet, unoxidized tests (Table IV-3). However, unfiltered concentrations of mercury and zinc in runoff from the dry, oxidized Inner Harbor sediment were equal to unfiltered concentrations from the wet, unoxidized sediment, but silver was greater.



Figure IV-3. Soil Bed of Anaerobic Oakland Harbor Sediment Just After a Simulated Rainfall Event

Unfiltered concentrations of mercury in runoff from the dry, oxidized Outer Harbor sediment were equal to concentrations from the wet, unoxidized sediment, but silver was again greater. Filtered concentrations of arsenic, silver, and mercury were not statistically different from unfiltered concentrations in samples collected in tests on either the Inner or Outer Harbor sediment. Arsenic, cadmium, chromium, copper, and zinc unfiltered concentrations in runoff samples collected from the Inner Harbor sediment were statistically greater than at least one of the assumed water quality criteria or standards, but only arsenic was statistically greater than any of the assumed criteria or standards for filtered samples. Arsenic, chromium, copper and zinc unfiltered concentrations in runoff samples collected from the Outer Harbor sediment were statistically greater than at least one of the assumed



Figure IV-4. Soil Bed of Dried and Oxidized Oakland Harbor Sediment Prior to Rainfall Simulation

water quality criteria or standards, and only arsenic was statistically greater than any of the assumed criteria or standards for filtered samples.

Unfiltered butyltin concentrations were not statistically less in runoff samples collected from the dry, oxidized sediments than in the wet, unoxidized sediment. Filtered butyltin concentrations in runoff samples from the Inner Harbor, dry oxidized sediment and unfiltered and filtered concentrations from the Outer Harbor, dry oxidized sediment were also not statistically different from the wet, unoxidized sediment. All tributyltin concentrations in samples from the dry, oxidized sediments were not statistically, greater than any of the assumed water quality criteria or standards.

Discussion

Changes did occur in the sediment during the drying and oxidation process, and surface runoff water quality was affected. Surface runoff pH levels

Table IV-2
Surface Runoff Physical Water Quality from Oakland
Harbor Sediments

<u>Parameter*</u>	(OH1) Inner, Wet <u>Sediment</u>	(OH1) Inner, Dry <u>Sediment</u>	(OH0) Outer, Wet <u>Sediment</u>	(OH0) Outer, Dry <u>Sediment</u>
Suspended Solids (mg/L)**	4447 A (3226-6124)	1686 B (1224-2324)	4610 A (3348-6355)	1749 B (1270-2409)
pH	7.97 A (7.74-8.19)	6.88 B (6.66-7.11)	8.11 A (7.88-8.33)	7.02 B (6.79-7.24)
Electrical Conductivity (mV/cm)	0.99 B (0.21-1.78)	2.41 AB (1.63-3.20)	1.55 AB (0.76-2.34)	2.97 A (2.18-3.75)

* Mean concentrations followed by the same letter within each parameter were not statistically significantly different.

** Numbers in parentheses represent the 95% confidence interval about the mean.

were statistically less after the sediment had dried and oxidized; however, the pH level remained near 7.0 for both the Inner and Outer Harbor sediments. This contrasts with many other sediments tested at the WES, where pH levels in runoff from dry, oxidized sediments ranged from 5.0 to 6.5. The two sediments were statistically less erosive after drying and oxidation. Electrical conductivity was not statistically reduced after drying and oxidation, however values were relatively low compared to many marine sediments.

Concentrations of heavy metals in surface runoff were highest in unfiltered samples collected from the wet, unoxidized sediments, and except for arsenic, silver and mercury, heavy metals were mostly insoluble and bound to the suspended solids during the wet, unoxidized stage of the sediments. Silver and mercury concentrations were close to or less than the detection limits where analytical variability was relatively high and statistical differences were not detected. Tributyltin concentrations were highest in the unfiltered runoff from the wet, unoxidized Inner Harbor sediment, but filtered concentrations were not statistically different between the sediments.

After drying and oxidation, concentrations of heavy metals in unfiltered surface runoff samples from both sediments were reduced. Concentrations of cadmium, chromium, copper, lead, and zinc in filtered samples, however, were not statistically reduced by the drying and oxidation process. Heavy metals

Table IV-3
Surface Runoff Chemical Water Quality From Oakland Harbor
Sediments (µg/L)

Parameter	Inner Sediment			
	Wet		Dry	
	Unfiltered	Filtered	Unfiltered	Filtered
Arsenic ** (µg/L)	22.5 A * (12.7-39.8)***	12.6 AB * (7.13-22.3)	3.72 B * (2.10-6.61)	2.08 B * (1.13-3.84)
Silver (µg/L)	0.16 C (0.13-0.20)	0.14 C (0.11-0.17)	1.11 AB (0.90-1.36)	0.93 B (0.74-1.16)
Cadmium (µg/L)	9.12 A **@ (5.60-14.8)	0.99 C (0.61-1.61)	2.69 B * (1.65-4.40)	0.29 D (0.17-0.49)
Chromium (µg/L)	78.0 A **@ (62.8-97.0)	2.97 C (2.39-3.70)	34.0 B **@ (27.3-42.4)	1.30 D (1.03-1.64)
Copper (µg/L)	162 A \$@** (130-203)	6.66 C \$ (5.32-8.33)	84.4 B \$@** (67.3-106)	3.46 D (2.72-4.40)
Mercury (µg/L)	0.0014 A (0.0005-0.0039)	0.0006 A (0.0004-0.0017)	0.0043 A (0.0015-0.0122)	0.0019 A (0.0006-0.0057)
Lead (µg/L)	46.0 A (32.9-64.5)	0.71 CD (0.51-0.99)	22.0 B (15.7-31.0)	0.34 D (0.24-0.49)
Zinc (µg/L)	395 A \$@** (250-627)	21.7 C (13.7-34.4)	206 A \$@** (130-328)	11.3 CD (6.91-18.6)
Tetrabutyltin (ng/L)	2.14 AB (1.65-2.78)	1.49 B (1.15-1.93)	3.38 A (2.63-4.33)	2.35 AB (1.77-3.12)
Tributyltin (ng/L)	47.9 A * (31.6-72.8)	22.5 AB (14.8-34.2)	16.2 B (10.9-24.3)	7.62 BC (4.84-12.0)
Dibutyltin (ng/L)	19.7 A (12.1-31.9)	8.85 AB (5.47-14.3)	13.1 AB (8.31-20.8)	5.89 B (3.49-9.94)
Monobutyltin (ng/L)	5.64 AB (3.02-10.5)	2.40 B (1.28-4.49)	13.2 A (7.28-24.1)	5.63 AB (2.85-11.1)

(Continued)

Table IV-3 (Concluded)

Parameter	Inner Sediment			
	Wet		Dry	
	Unfiltered	Filtered	Unfiltered	Filtered
Arsenic ($\mu\text{g/L}$)	32.0 A * (17.4-58.9)	17.9 A * (10.1-31.8)	5.29 B * (2.99-9.35)	2.96 B * (1.67-5.23)
Silver ($\mu\text{g/L}$)	0.21 C (0.17-0.27)	0.18 C (0.15-0.22)	1.45 A (1.18-1.78)	1.22 AB (0.99-1.50)
Cadmium ($\mu\text{g/L}$)	3.19 B ** (1.89-5.38)	0.35 D (0.21-0.57)	0.94 C (0.58-1.53)	0.10 E (0.06-0.17)
Chromium ($\mu\text{g/L}$)	69.3 A @** (54.9-87.5)	2.64 C (2.12-3.29)	30.2 B @** (24.3-37.6)	1.15 D (0.93-1.43)
Copper ($\mu\text{g/L}$)	155 A \$@** (148-522)	6.33 C (2.18-10.2)	80.2 B \$@** (29.3-106)	3.29 D (1.59-8.11)
Mercury ($\mu\text{g/L}$)	0.0007 A ($<0.0004-0.0020$)	0.0003 A ($<0.0004-0.0008$)	0.0020 A (0.0007-0.0057)	0.0009 A ($<0.0004-0.0025$)
Lead ($\mu\text{g/L}$)	65.2 A ** (45.4-93.6)	1.01 C (0.72-1.41)	31.2 B (22.3-43.8)	0.48 D (0.34-0.67)
Zinc ($\mu\text{g/L}$)	294 A \$@** (179-482)	16.2 CD (10.1-25.7)	153 B \$** (96.8-243)	8.41 D (5.31-13.3)
Tetrabutyltin (ng/L)	1.81 B (1.37-2.40)	1.26 B (0.96-1.64)	2.85 AB (2.20-3.70)	1.98 B (1.50-2.62)
Tributyltin (ng/L)	16.0 B (10.2-25.1)	7.51 BC (4.90-11.5)	5.42 C (3.57-8.22)	2.54 C (1.63-3.97)
Dibutyltin (ng/L)	16.1 AB (9.55-27.0)	7.19 B (4.41-11.7)	10.7 AB (6.62-17.3)	4.79 B (2.87-8.00)
Monobutyltin (ng/L)	3.65 B (1.86-7.18)	1.55 B (0.82-2.94)	8.58 AB (4.60-16.0)	3.65 B (1.87-7.10)

* Mean concentration was statistically greater than the assumed Receiving Water Limitation Criteria.

** Mean concentrations followed by the same letter within each parameter were not statistically different.

*** Numbers in parentheses represent the 95% confidence interval about the mean.

Mean concentration was statistically greater than the assumed Effluent Limitation Criteria.

@ Mean concentration was statistically greater than the assumed USEPA Fresh Water Acute Criteria.

\$ Mean concentration was statistically greater than the assumed USEPA Marine Water Criteria.

Table IV-4
Surface Runoff Contaminants Exceeding
Water Quality Criteria or Standards

<u>Parameter</u>	<u>USEPA* Marine Acute Criteria</u>	<u>USEPA* Fresh Acute Criteria</u>	<u>Effluent** Limitation Standards</u>	<u>Receiving Water** Limitation Standards</u>
<u>Inner Sediment</u>				
Unfiltered, wet, unoxidized	Copper Zinc	Cadmium Chromium Copper Zinc	Cadmium Chromium Copper Zinc	Arsenic Cadmium Chromium Copper Zinc Tributyltin
Filtered, wet, unoxidized	Copper	none	none	Arsenic
Unfiltered, dry, oxidized	Copper Zinc	Chromium Copper Zinc	Chromium Copper Zinc	Arsenic Cadmium Chromium Copper Zinc
Filtered, dry, oxidized	none	none	none	Arsenic
<u>Outer Sediment</u>				
Unfiltered, wet, unoxidized	Copper Zinc	Chromium Copper Zinc	Cadmium Chromium Copper Lead Zinc	Arsenic Cadmium Chromium Copper Lead Zinc
Filtered, wet, unoxidized	none	none	none	Arsenic
Unfiltered, dry, oxidized	Copper Zinc	Chromium Copper Zinc	Chromium Copper Zinc	Arsenic Chromium Copper Zinc
Filtered, dry, oxidized	none	none	none	Arsenic

* In the absence of State Water Quality Standards, it was assumed that the Federal Water Quality Criteria would apply.

** See Table IV-1.

in runoff from both the sediments were more soluble after drying and oxidation, however a large portion of the heavy metals in surface runoff remained bound to the particulates.

Concentrations in surface runoff of many of the heavy metals were statistically greater than one or more of the assumed water quality criteria or standards in unfiltered samples from the wet, unoxidized sediments (Table IV-4). Tributyltin concentrations in unfiltered runoff from the Inner Harbor sediment also exceeded the assumed Receiving Water Limitation Standards. Copper concentrations in filtered surface runoff samples from the Inner Harbor sediment statistically exceeded assumed the EPA Acute criteria for marine environments. Only arsenic concentrations in the dry, oxidized Inner and Outer Harbor sediments filtered runoff samples were statistically greater than the assumed Receiving Water Limitation Standards. The difference, however, was only about 1 $\mu\text{g/L}$. Several heavy metal parameters in unfiltered runoff samples from both dry, oxidized sediments were statistically greater than one or more of the assumed criteria or standards. Tributyltin concentrations, however, were not statistically greater than any of the criteria or standards. Only arsenic in filtered runoff samples from both of the dry, oxidized sediments exceeded the assumed Receiving Water Limitation Standards.

Surface Runoff Impacts and Controls

Contaminants in surface runoff from the Inner and Outer Oakland Harbor sediments were mostly bound to the sediment particulates. Significant quantities of arsenic, cadmium, chromium, copper, zinc, and tributyltin could be eroded from an upland disposal site during the wet, unoxidized stage, if the suspended solids were not removed from the runoff. Generally surface runoff concentrations from the Inner Harbor sediment were not significantly different than concentrations from the Outer Harbor sediment.

Potential surface runoff water quality problems during the wet, unoxidized period of upland disposal would mostly be associated with erosion of particulates. Management of the upland disposal site to remove particulates from surface runoff, would remove 90 to 99 percent of all contaminants in surface runoff. Only soluble copper concentrations in runoff from the Inner sediment exceeded the assumed EPA Acute water quality criteria for marine environments and soluble arsenic exceeded the Receiving Water Limitation Standards. Soluble arsenic concentrations exceeded the assumed Receiving Water Limitation Standards in runoff from the Outer harbor sediment but copper did not exceed the assumed EPA criteria. Consideration of a mixing zone at the

discharge point from the upland disposal site and/or further treatment will be required for those soluble contaminants. A mixing zone ratio of about 10 to 1, receiving water to runoff water, would be required to dilute arsenic concentrations in surface runoff water to the assumed Receiving Water Limitation Standards. A ratio of 3 to 1 would be required to dilute copper concentrations to the assumed EPA water quality criteria for marine environments.

Potential problems in surface runoff from dry, oxidized sediments should occur only from copper, chromium, zinc, cadmium and arsenic bound to the suspended solids. Only soluble arsenic exceeded the Receiving Water Limitation Standards in both sediments. Consideration of a mixing zone or removal of the suspended solids should eliminate the need for further restrictions particularly with regard to treatment of soluble contaminants. Establishment of vegetation either by natural succession or by planting would further reduce contaminant concentrations in surface runoff. A mixing zone of less than 10 to 1 will be required to dilute unfiltered contaminant concentrations to less than or equal to the strictest assumed criteria or standard, and a mixing zone of about 2 to 1 will be required for soluble arsenic.

Biological Evaluation

Methods and Materials

Aquatic bioassay tests were performed on whole, unfiltered water samples obtained from the WES rainfall simulator. This system provides replicate water samples on consecutive days for chemical analyses. For these bioassays, gallon samples from three days were composited and tested as one runoff sample. Samples generally were clear liquid with a 0.5 cm layer of grey sediment at the bottom of the jar. This sediment was resuspended to the water column prior to the bioassay tests. Salinity of the runoff samples was very low, 0 to 1 parts per thousand (ppt). Bioassays were conducted at three salinities (0 to 1 ppt or freshwater, 12 ppt, and 24 ppt) by using a small volume of high salinity (80-ppt) laboratory water to adjust the runoff sample. Test species were *Daphnia magna* (freshwater tests) and a Pacific mysid species, *Neomysis mercedes*, for the estuarine and marine tests. The animals were exposed to different percentages of unfiltered water samples for 96 hours in a temperature-controlled environmental chamber. Test temperatures were 18-20 °C and photoperiod was 14:10 hours L:D. Test chambers were one liter beakers, each containing 800 ml of test water and 10 test animals; there were five replicate

beakers for each test treatment. Suspended sediment was allowed to settle during the bioassay. Controls were exposed to clean laboratory water used to hold and culture the *Daphnia* and *Neomysis*. This water was also used to dilute the runoff water when necessary. For example a 50 % beaker contained 400 ml of runoff water and 400 ml of clean culture water of the proper salinity. Test animals were observed during the tests but actual counts of each beaker were only possible at the end of the 96-hour test period. Dissolved oxygen concentrations in the beakers were normally greater than 6 parts per million (ppm) and at times were measured as high as 12-14 ppm due to algae growth. The pH levels of the test waters were in the normal range for saltwater, 7.6 - 8.4 and were lower for the freshwater tests, 7.2 - 7.4.

All bioassays were started within 3 to 5 days after water samples were obtained. Samples were held under refrigeration while waiting for the next days sample, or while animals or test equipment was being prepared. It was not possible to conduct all of the bioassays at the various salinities simultaneously. Each set of bioassays (Oakland Inner or Oakland Outer Harbor) took approximately 2 weeks to complete.

Results and Discussion

Tables IV-5 to IV-10 show percent survival of *Daphnia* and *Neomysis* exposed to different concentrations of runoff water compared to controls. *Daphnia* results are presented in Tables IV-5 and IV-10. Following those data are the *Neomysis* at 12-ppt and *Neomysis* at 24-ppt salinity. There are six Tables - three for Oakland Inner Harbor and three for Oakland Outer Harbor. Tables IV-11 and IV-12 show *Daphnia* bioassays of dried sediment runoff water.

Exposure of these sensitive test animals to Oakland sediment runoff waters shows little potential for aquatic toxicity. Mean survival was usually greater than 90 percent for all treatments, even for animals exposed to 100 percent runoff water. Where a lower survival rate was shown, such as for the *Neomysis* exposed to Oakland Outer Harbor at 24-ppt salinity, the data for the controls also revealed some beakers with lower survival. The *Daphnia*, in some cases, showed evidence that fine sediment particles were attaching to their bodies and physically affecting them. Fine sediment particles may have made it more difficult for them to swim normally. This was more likely to occur during the dry sediment (after six months) bioassays. The mysids were sometimes prone to damage while being placed in the exposure beakers. If these animals were not identified immediately, then they were counted as casualties the next day or at the end of the test. These factors may account for 1 or 2

(out of the 50 individuals) of the casualties observed in each of the bioassays. Thus the data from these bioassays do not, in any way, indicate aquatic toxicity associated with these runoff waters.

Table IV-5

Percent Survival of Daphnia Exposed to Anaerobic Oakland Inner Harbor
Sediment Runoff Water for 96 Hours

<u>Treatment</u>	<u>Replicate</u>	<u>Percent Survival</u>
Controls	1	100
	2	100
	3	100
	4	100
	5	100
10 %	1	100
	2	100
	3	80
	4	80
	5	70
50 %	1	100
	2	90
	3	100
	4	100
	5	100
100 %	1	100
	2	100
	3	100
	4	100
	5	100

Table IV-6

Percent Survival of Neomysis Exposed to Anaerobic Oakland Inner Harbor
Sediment Runoff Water at 12-ppt Salinity for 96 Hours

<u>Treatment</u>	<u>Replicate</u>	<u>Percent Survival</u>
Controls	1	100
	2	100
	3	100
	4	100
	5	100
10 ‰	1	100
	2	100
	3	100
	4	100
	5	100
50 ‰	1	100
	2	100
	3	100
	4	100
	5	100
100 ‰	1	90
	2	100
	3	90
	4	90
	5	100

Table IV-7

Percent Survival of Neomysis Exposed to Anaerobic Oakland Inner Harbor
Sediment Runoff Water at 24-ppt Salinity for 96 Hours

<u>Treatment</u>	<u>Replicate</u>	<u>Percent Survival</u>
Controls	1	100
	2	100
	3	100
	5	100
10 ‰	1	100
	2	100
	3	100
	5	100
50 ‰	1	100
	2	100
	3	100
	5	90
100 ‰	1	100
	2	100
	3	90
	4	100
	5	80

Table IV-8

Percent Survival of Daphnia Exposed to Oakland Outer Harbor Sediment
Runoff Water for 96 Hours

<u>Treatment</u>	<u>Replicate</u>	<u>Percent Survival</u>
Controls	1	90
	2	100
	3	100
	4	90
	5	100
10 %	1	100
	2	100
	3	90
	4	90
	5	90
50 %	1	40
	2	100
	3	80
	4	90
	5	80
100 %	1	100
	2	90
	3	90
	4	90
	5	80

Table IV-9

Percent Survival of Neomysis Exposed to Oakland Outer Harbor Sediment
Runoff Water at 12-ppt Salinity for 96 Hours

<u>Treatment</u>	<u>Replicate</u>	<u>Percent Survival</u>
Controls	1	80
	2	70
	3	100
	4	100
	5	70
10 ‰	1	100
	2	70
	3	80
	4	80
	5	100
50 ‰	1	80
	2	100
	3	100
	4	80
	5	70
100 ‰	1	80
	2	100
	3	100
	4	100
	5	80

Table IV-10

Percent Survival of Neomysis Exposed to Oakland Outer Harbor Sediment
Runoff Water at 24-ppt Salinity for 96 Hours

<u>Treatment</u>	<u>Replicate</u>	<u>Percent Survival</u>
Controls	1	70
	2	50
	3	70
	4	100
	5	100
50 %	1	80
	2	70
	3	80
	4	80
	5	70
100 %	1	100
	2	80
	3	100
	4	80
	5	70

* The 10% treatment not conducted due to the availability of test animals and because previous Oakland Outer tests (at 0 and 12 ppt) had not demonstrated any toxicity.

Table IV-11

Percent Survival of Daphnia Exposed to Oxidized Oakland Inner
Harbor Sediment Runoff Water for 96 Hours

<u>Treatment</u>	<u>Replicate</u>	<u>Percent Survival</u>
Controls	1	100
	2	100
	3	100
	4	100
	5	100
50 %	1	90
	2	100
	3	90
	4	100
100 %	1	90
	2	80
	3	80
	4	90
	5	90

Table IV-12
Percent Survival of Daphnia Exposed to Oxidized Oakland Outer
Harbor Sediment Runoff Water for 96 Hours

<u>Treatment</u>	<u>Replicate</u>	<u>Percent Survival</u>
Controls	1	100
	2	100
	3	100
	4	100
	5	100
50 %	1	100
	2	100
	3	100
	4	100
	5	100
100 %	1	100*
	2	100
	3	100
	4	100
	5	100

* An earlier bioassay of dry Oakland Outer 100 % indicated toxicity associated with fine sediment particles in unfiltered elutriates.

PART V: LEACHATE TEST

When contaminated dredged material is placed in a confined disposal facility, contaminants may be mobilized and transported to the site boundaries by leachate generation and seepage. Subsurface drainage through foundation soils and dikes may then reach adjacent surface and ground waters and act as a source of contamination. Many chemical processes potentially affect leachate quality in dredged material, including sorption, ion-exchange, dissolution and precipitation, oxidation-reduction, and complexation. Leachate flow and generation is also affected by the hydraulic properties of the dredged material and the disposal site hydrogeology.

Laboratory tests and predictive techniques are under development that are designed to provide a basis for evaluating potential leachate impacts (Hill, Myers, and Brannon 1988; Louisiana Water Resources Research Institute 1990; Myers, Brannon, and Price 1992). The laboratory procedures and interpretation protocols used in this report are still developmental; thus, descriptions, applications, and limitations of the procedures are required.

Methods and Materials

Oxidized Sediment Preparation

Sediment used in aerobic testing was first placed into 38-l glass aquariums to a depth of approximately 6 cm. The sediment was allowed to oxidize at ambient temperature. Each week the sediment was thoroughly mixed to expose fresh sediment surfaces to the air. When necessary, deoxygenated distilled-deionized (DDI) water was added to the sediment to maintain the original moisture condition. At the end of six months, the sediment was again thoroughly mixed before being used in testing.

Kinetic Batch Testing

Batch testing was performed to determine shaking time necessary to achieve equilibrium or steady-state concentrations of metals and butyltin in leachate. The general experimental sequence is presented in Table V-1.

For testing metal releases from anaerobic Oakland Inner and Outer Harbor sediments, triplicate 250-ml polycarbonate centrifuge tubes fitted with a leakproof, airtight top were loaded with 200 g of sediment and deoxygenated distilled-deionized (DDI) water at a 4:1 water-to-sediment dry weight ratio. All operations were conducted in a glove box under a nitrogen atmosphere

Table V-1

Experimental Sequence for Determining Appropriate Shaking Times
for Kinetic Testing of Oakland Harbor Sediments

-
- | | |
|--------|---|
| Step 1 | PLACE SEDIMENT IN APPROPRIATE CENTRIFUGE TUBE (STAINLESS STEEL OR POLYCARBONATE), ADD SUFFICIENT DEOXYGENATED-DISTILLED WATER TO MAINTAIN WATER-TO-SEDIMENT RATIO OF 4:1. |
|--------|---|
-
- | | |
|--------|---|
| Step 2 | PLACE CENTRIFUGE TUBES FOR METALS ON RECIPROCATING SHAKER AND SHAKE AT 160 CYCLES PER MINUTE. PLACE CENTRIFUGE TUBES FOR TRIBUTYL TIN AND PAHs IN ROTARY MIXER AND TURN AT 40 REVOLUTIONS PER MINUTE. |
|--------|---|
-
- | | |
|--------|---|
| Step 3 | REMOVE TUBES (ENOUGH FOR TRIPLICATE SAMPLES) FROM SHAKER AT APPROPRIATE INTERVALS: 1, 2, AND 7 DAYS FOR TRIBUTYL TIN AND PAHs AND 6 HR, 1, 2, 3, 7, AND 10 DAYS FOR METALS. |
|--------|---|
-
- | | |
|--------|---|
| Step 4 | CENTRIFUGE FOR 30 MINUTES AT 6,500 X g FOR TRIBUTYL TIN AND PAHs AND 13,000 x g FOR METALS. |
|--------|---|
-
- | | |
|--------|--|
| Step 5 | FILTER CENTRIFUGED LEACHATE THROUGH A 0.45- μ m PORE SIZE MEMBRANE FILTER FOR METALS, AND THROUGH A WHATMAN GF/D GLASS-FIBER PREFILTER AND A GELMAN AE GLASS-FIBER FILTER WITH A 1- μ m NOMINAL PORE SIZE FOR TRIBUTYL TIN AND PAHs. |
|--------|--|
-
- | | |
|--------|--|
| Step 6 | ACIDIFY LEACHATE FOR METALS AND PAH ANALYSIS WITH ULTREX NITRIC ACID. STORE SAMPLES FOR ANALYSIS OF TRIBUTYL TIN AND PAHs IN GLASS BOTTLES AND FREEZE UNTIL ANALYSIS. STORE LEACHATE FOR METALS ANALYSIS IN PLASTIC BOTTLES. |
|--------|--|
-

(Figure V-1). Nineteen centrifuge tubes were loaded to allow triplicate sampling at 6 hrs, and at 1, 2, 3, 7, and 10 days and a procedure blank. Samples were placed horizontally on a reciprocating shaker at 160 strokes per minute (spm) for the allotted time. Three tubes for each sediment (Oakland Inner and Outer Harbor sediments) were removed from the shaker and centrifuged at 9,000 rpm (13,000 x g) for 30 minutes. The supernatant was filtered under a nitrogen atmosphere through 0.45- μ m membrane filters (Figure V-2). The filtrate was acidified to pH 1 with concentrated Ultrex nitric acid and stored in plastic bottles until analyzed.



Figure V-1. Anaerobic Sediments Were Leached Under a Nitrogen Atmosphere in a Glove Box

Kinetic testing for tributyltin and PAHs in anaerobic Oakland Inner and Outer sediment was conducted in specially fabricated 450-ml stainless steel centrifuge tubes (Figure V-3). Twenty-one centrifuge tubes (sufficient for three replicates), double-rinsed with acetone, were loaded with sufficient sediment and deoxygenated DDI water to obtain a 4:1 water-to-sediment dry weight ratio. The total mass (approximately 350 g) of sediment and water was adjusted to allow the tube to be safely centrifuged at 6,200 rpm (6,500 x g). All operations were conducted under a nitrogen atmosphere. The tubes were placed in a rotary tumbler and turned end over end at 40 rpm for periods of 1, 2, and 7 days. At the appointed times, the samples were removed from the tumbler and centrifuged for 30 min. Resulting supernatants were filtered through a Whatman GF/D prefilter and a Gelman AE filter with a nominal pore size of 1.0 μm . The filters (Whatman GF/D prefilters and Gelman AE filters)



Figure V-2. Filtering of Anaerobic Sediment Leachates Are Performed in a Nitrogen Atmosphere

are binderless, glass-fiber containing no detectable organic contaminants. As a further precaution against contamination, the filters were combusted at 400 °C prior to use. Filtration was conducted under a nitrogen atmosphere; samples for tributyltin were frozen immediately in acetone-rinsed 2-L glass bottles and kept frozen until analyzed. Samples for PAHs were acidified with a few drops of Ultrex nitric acid and refrigerated at 4 °C in acetone-rinsed 2-L glass bottles until analyzed.

Sequential Batch Testing

A 4:1 water-to-sediment ratio and a shaking time of 24 hr were used in the sequential batch leach tests for Oakland Harbor sediments. General test procedures for assessing steady-state leachate and sediment metal, PAH, and tributyltin concentrations are detailed in Table V-2. Sequential batch tests for metals under anaerobic conditions were conducted in triplicate 250-ml



Figure V-3. Centrifuge Tubes With Anaerobic Sediment Are Stored Under a Nitrogen Atmosphere

polycarbonate centrifuge bottles with leakproof caps. Each centrifuge tube was loaded under a nitrogen atmosphere with anaerobic Oakland Harbor (Inner or Outer) sediment and deoxygenated DDI water to a 4:1 water-to-sediment ratio. Tubes were mechanically shaken for 24 hr and centrifuged at $13,000 \times g$ for 30 min. Most of the leachate from each 250-ml centrifuge bottle was filtered through a $0.45\text{-}\mu\text{m}$ membrane filter. The unfiltered leachate was analyzed for pH using a combination electrode and a millivolt meter and for conductivity using a Yellow Springs Instrument Company conductivity meter and cell. Fresh deoxygenated DDI water was added to replace the leachate removed for analysis. The procedure described above for sequentially contacting anaerobic Oakland Harbor sediment with clean water was repeated seven times. The same general procedure was repeated for aerobic batch leach tests for metals, except that anaerobic conditions were not maintained.

Table V-2

Test Sequence for Sequential Batch Leaching of Anaerobic Oakland
Harbor Sediment for Metals, PAHs and Tributyltin

-
- Step 1 LOAD SEDIMENT INTO APPROPRIATE CENTRIFUGE TUBES; 250-ML POLYCARBONATE FOR METALS AND 450-ML STAINLESS STEEL FOR TRIBUTYLTIN AND PAHs. ADD SUFFICIENT WATER TO EACH TUBE TO BRING FINAL WATER-TO-SEDIMENT RATIO TO 4:1. LOAD SUFFICIENT NUMBER OF STAINLESS STEEL TUBES TO OBTAIN SUFFICIENT LEACHATE FOR ANALYSIS.
-
- Step 2 GO THROUGH STEP 2 IN TABLE V-1.
-
- Step 3 CENTRIFUGE FOR 30 MIN AT 6,500 x g FOR TRIBUTYLTIN AND PAHs AND 13,000 x g FOR METALS.
-
- Step 4 FILTER LEACHATE THROUGH 0.45- μ m MEMBRANE FILTERS FOR METALS OR THROUGH WHATMAN GD/F GLASS-FIBER PREFILTERS FOLLOWED BY GELMAN AE GLASS-FIBER FILTERS OF 1.0- μ m NOMINAL PORE SIZE FOR TRIBUTYLTIN AND PAHs. SET ASIDE A SMALL AMOUNT OF LEACHATE PRIOR TO ACIDIFICATION FOR ANALYSIS OF pH, CONDUCTIVITY, AND TOC.
-
- Step 5 RETURN TO STEP 2 AFTER REPLACING LEACHATE WITH DEOXYGENATED-DISTILLED WATER. REPEAT THE ENTIRE PROCEDURE THE DESIRED NUMBER OF TIMES.
-

Notes: Testing sequence is the same for aerobic sediments except that anaerobic integrity is not maintained.

Testing of Oakland Harbor sediment for butyltin and PAH compounds was conducted as described for metals, except that 450-ml stainless steel centrifuge tubes were used. Filtration procedures used for butyltin and PAH compounds were as previously described for butyl tin and PAH kinetic batch testing. A subsample of filtered leachate was set aside from both the anaerobic and aerobic tests for analysis of total organic carbon. After each cycle, the sediment was remixed with DDI water, shaken for 24 hr, and then processed as previously described. Three replicates were taken through six leach cycles for the anaerobic and aerobic testing.

Column Leach Testing

Column leach tests were conducted in large diameter-to-length columns designed specifically for sediment and dredged material leaching (Figure V-4). The apparatus was designed to simulate anaerobic leaching of dredged material in a continuous flow mode, minimize wall effects, hold pore water velocities to about 10^{-5} cm/sec or less, elute 10 or more pore volumes in six months, and produce sufficient sample volume for chemical analysis of fractional pore volume samples. Design of a leaching column with these performance

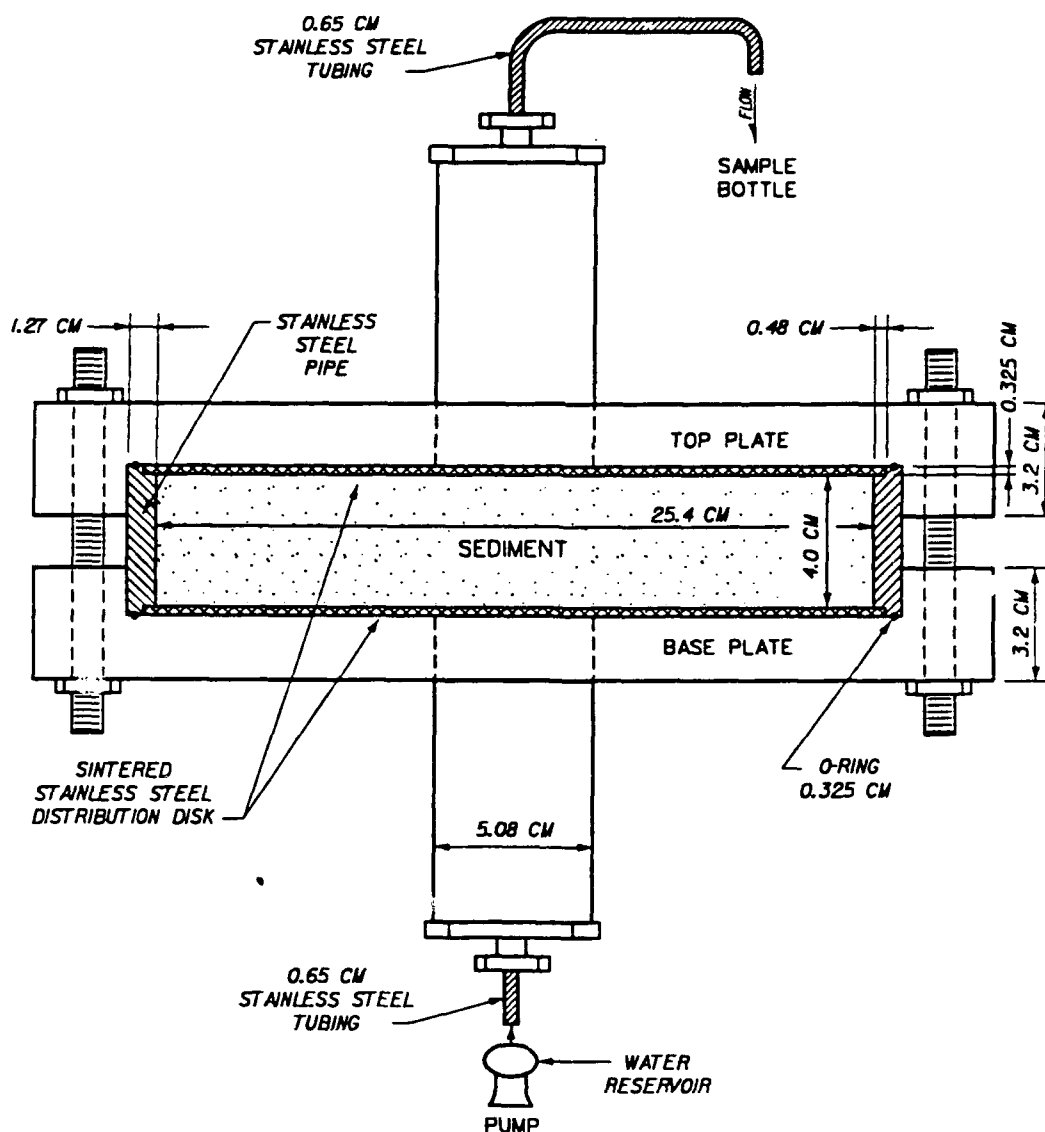


Figure V-4. Dredged Material Leaching Column

characteristics for sediments with low hydraulic conductivities was described by Myers, Gambrell, and Tittlebaum (1991).

Sediment was placed in leaching columns at in-situ water content in small increments, and manually vibrated with a spatula to eliminate air voids. Since the water content of the sediment was high, the sediment was easily worked using manual vibration techniques. Water content and specific gravity were determined according to methods described in EM 1110-2-1906 (Corps of Engineers 1970). These data were used to calculate sediment porosity. After the columns were filled, distilled-deionized water was pumped in upflow mode through the columns with constant volume pumps.

Separate column leach tests were run for metals and organic contaminant analysis because of the differences in sample volumes needed to conduct metal analysis (approximately 100 ml) and organic analysis (approximately 1000 ml) and different preservation techniques required. Column leach tests were conducted in triplicate for metals and in duplicate for organics. For each column leachate sample, the volume of leachate and time of collection were recorded. As leachate for metals was collected, pH was manually adjusted on a daily basis to less than 2 using Ultrex nitric acid. Leachates for PAH and tributyltin analysis were collected in amber, acetone rinsed, glass jars and stored at 4 °C until shipped for analysis. Samples were shipped on ice by overnight delivery. Leachates from columns conducted for organics were not pH adjusted or otherwise altered. After each leachate sample for chemical analysis (metals or organics) was collected, an additional sample of 15 to 20 ml was collected and analyzed for pH and electrical conductivity.

Chemical Analysis

Leachate and sediment samples were analyzed by Battelle Northwest Marine Sciences Laboratory, Sequim, WA for tetrabutyltin (TETBT), tributyltin (TBT), dibutyltin (DBT), monobutyltin (MBT), naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)-anthracene, chrysene, benzo(b) + benzo(k)-fluoranthene, benzo(a)-pyrene, indeno-(1,2,3-c,d)-pyrene, dibenzo(a,h)-anthracene, benzo(g,h,i)-perylene, nickel (Ni), selenium (Se), silver (Ag), cadmium (Cd), lead (Pb), mercury (Hg), arsenic (As), zinc (Zn), chromium (Cr), and copper (Cu).

Data and Statistical Analysis

All statistical analyses were conducted using methods developed by the Statistical Analysis Systems Institute (Barr et al. 1976). To test for differences between means, analysis of variance procedures were used. Prior to

computation and analysis of data, method blanks were subtracted from analytical values for butyltin and PAH compounds. When all leachate values were below detection limits, data for that compound are not presented in tabular form within the main body of the report.

Results

Sediment Bulk Chemistry

Concentrations of sediment metals, butyltin compounds, and PAH compounds are presented in Section II of this report. Concentrations of PAH and butyltin compounds following six months of aerobic incubation are presented in Table V-3. Concentrations of both butyltin and PAH compounds were generally lower in concentration in the aerobic sediments compared to the anaerobic sediments. The difference in organic contaminant concentrations between aerobic and anaerobic sediment is probably due to volatilization and biodegradation during the incubation process.

Kinetic Batch Testing

Kinetic batch testing was performed to confirm previous experiments indicating that a 24 hour shaking time was sufficient to achieve steady-state conditions. To test this hypothesis, 1 day concentrations were compared to concentrations obtained at other sampling times. Results showed no significant differences ($P < 0.05$) for metals and butyltin compounds in anaerobic Oakland Inner Harbor sediments (Table V-4) in levels of leachate Zn, Cu, Ni, Ag, Cd, tributyltin, dibutyltin, and monobutyltin. Therefore, one day of shaking for these compounds will reflect the highest leachate concentrations observable. Mercury concentrations were highest at the 6 hr sampling, but concentrations at the 1 day sampling did not significantly differ from concentrations at later sampling times. Arsenic leachate concentrations at 1 day were statistically equivalent to all but the 2, 3, and 10 day concentrations, which were higher. Lead concentrations at 1 day were only exceeded by concentrations following 2 days.

Kinetic testing results for metals and butyltin compounds in anaerobic Oakland Outer Harbor sediment (Table V-5) showed that leachate Zn, Ni, Ag, Pb, Cd, Hg, tributyltin, dibutyltin, and monobutyltin concentrations following 1 day of shaking were no different from leachate concentrations at later sampling periods. These results indicated that steady-state concentrations of

Table V-3

Concentrations of PAH and Butyltin Compounds ($\mu\text{g/kg}$) in Aerobic
Oakland Harbor Sediments Following Six Months of Incubation

<u>Parameter</u>	<u>(OH1) Oakland Inner</u>	<u>(OH0) Oakland Outer</u>
Benzo(b,j,k)fluoranthene	94.4	86.0
Benzo(a)pyrene	69.0	53.8
Indeno(1,2,3-c,d)pyrene	56.9	24.4
Benzo(g,h,i)-perylene	45.2	18.2
Naphthalene	<2.1	<3.1
Phenanthrene	<19.7	20.3
Fluoranthene	72.2	58.6
Pyrene	143.5	105.1
Benzo(a)-anthracene	<2.1	25.0
Chrysene	30.3	34.1
Acenaphthylene	<2.1	<3.1
Fluorene	<2.1	<3.1
Anthracene	<2.1	<3.1
Acenaphthene	<2.1	<3.1
Tetrabutyltin	<2.4	<2.4
Tributyltin	2.0J	2.7
Dibutyltin	4.1	1.8J
Monobutyltin	<5.1	<5.1

these metals had been reached in 1 day. Only As, Cu, and Cr exhibited higher leachate concentrations at sampling times of 2 days or more.

Kinetic testing results in anaerobic Oakland Inner and Outer Harbor sediments (Tables V-6 and V-7, respectively) showed that PAH concentrations following 1 day of shaking were no different from leachate concentrations at later sampling periods. Detection limits varied from sample to sample, but were generally between 8.9 and 22.2 ng/L. Average values below these levels are often noted in Tables V-6 and V-7 and reflect trace amounts in one or more replicate samples at a specific sampling time.

In past leaching studies with sediments from Indiana Harbor, Indiana (Environmental Laboratory 1987a and 1987b) and Everett Harbor, Washington (Palermo et al. 1989), 1 day was sufficient for steady-state or worst case metal concentrations to be achieved.

Sequential Batch Leaching

General leachate quality. Leachate pH and conductivity for anaerobic and aerobic sequential batch leaching tests for Oakland Harbor sediments are

Table V-4

Heavy Metal* and Butyltin** Concentrations in Leachate from Anaerobic
Oakland Harbor Inner Sediment at Different Sampling Times

Parameter	6 HR	Sampling Times			
		DAY 1	DAY 2	DAY 3	DAY 7
As	4.41(0.24)	5.58(0.36)	8.55(0.33)	7.20(0.18)	6.48(1.13)
Zn	14.6(1.25)	17.5(1.87)	29.9(10.5)	19.0(1.93)	21.0(0.76)
Cu	7.34(0.35)	9.48(0.80)	9.61(0.06)	9.17(0.41)	10.1(0.17)
Ni	8.35(0.16)	11.3(0.29)	13.0(0.65)	16.0(2.45)	13.1(0.08)
Cr	5.16(0.46)	5.33(0.39)	5.21(0.10)	6.80(0.60)	5.23(0.19)
Ag	0.53(0.02)	0.70(0.15)	0.64(0.09)	0.59(0.03)	0.53(0.01)
Pb	0.44(0.13)	0.38(0.07)	0.93(0.14)	1.85(0.92)	0.32(0.02)
Cd	0.38(0.05)	0.45(0.04)	0.47(0.03)	0.51(0.02)	0.44(0.03)
Hg	0.14(0.04)	0.04(0)	0.04(0)	0.05(0.01)	0.05(0.01)
Monobutyltin	NT***	0.35(0.29)	1.93(1.94)	NT***	0.97(0.97)
Dibutyltin	NT***	5.1(0.99)	6.5(5.11)	NT***	2.47(0.62)
Tributyltin	NT***	2.4(1.59)	3.63(0.88)	NT***	1.9(1.31)
Tetrabutyltin	NT***	1.1(1.1)	<1.4-2.6	NT***	<1.8-2.5

* Expressed in micrograms per liter (standard error in parentheses).

** Expressed in nanograms per liter (standard error in parentheses).

*** Not tested.

Table V-5

Heavy Metal* and Butyltin** Concentrations in Leachate from Anaerobic
Oakland Harbor Outer Sediment at Different Sampling Times

Parameter	Sampling Times				
	6 HR	DAY 1	DAY 2	DAY 3	DAY 7
As	14.5(2.32)	31.0(1.48)	50.6(4.29)	110(8.12)	71.6(5.41)
Zn	39.5(4.55)	58.8(8.07)	43.0(5.68)	27.0(2.37)	25.8(0.95)
Cu	34.1(2.70)	40.9(3.46)	46.2(1.17)	55.6(4.24)	56.4(2.13)
Ni	44.8(4.55)	61.5(11.1)	60.5(3.49)	55.4(0.89)	54.5(3.45)
Cr	5.3(1.13)	4.29(0.10)	14.2(3.33)	9.27(1.25)	9.45(0.72)
Ag	1.36(0.02)	1.51(0.01)	1.86(0.32)	1.67(0.06)	1.79(0.07)
Pb	0.85(0.09)	0.96(0.04)	0.71(0.08)	0.78(0.03)	2.15(1.27)
Cd	<1.00	0.31(0.12)	0.40(0.20)	0.62(0.09)	0.65(0.13)
Hg	0.07(0.02)	0.05(0)	0.01(0)	0.06(0)	0.06(0)
Monobutyltin	NT***	<2.6-2.7	0.83(0.83)	NT***	5.53(5.54)
Dibutyltin	NT***	5.85(0.78)	2.77(1.13)	NT***	3.2(3.20)
Tributyltin	NT***	3.75(2.66)	5.73(3.81)	NT***	1.23(1.24)
Tetrabutyltin	NT***	<2.8-2.9	0.8(0.80)	NT***	<1.7-2.5

* Expressed in micrograms per liter (standard error in parentheses).

** Expressed in nanograms per liter (standard error in parentheses).

*** Not tested.

Table V-6

PAH Concentrations* in Leachate from Anaerobic Oakland
Harbor Inner Sediment at Different Sampling Times

Parameter	Sampling Times		
	DAY 1	DAY 2	DAY 7
Benzo(b,k)-fluoranthene	<5.1-5.3	4.1(3.35)	<5.1-5.4
Benzo(a)-pyrene	<4.1-4.4	4.7(3.84)	<4.1-4.3
Naphthalene	87.3(15.4)	33.2(0.12)	<27.0-28.6
Phenanthrene	<19.9	<19.9	3.77(2.29)
Fluoranthrene	1(1.00)	0.35(0.29)	8.27(4.44)
Pyrene	57.9(7.31)	42.1(5.48)	56.2(12.1)
Benzo(a)-anthracene	<4.8-4.9	<4.8-5.4	5.1(2.56)
Chrysene	4.23(2.18)	5(0.74)	5.7(0.85)
Anthracene	2.03(2.04)	<4.9	1.8(1.80)
Acenaphthene	4.5(4.51)	<10.5	11.2(5.62)

* Expressed in nanograms per liter (standard error in parentheses).

Table V-7

PAH Concentrations* in Leachate from Anaerobic Oakland
Harbor Outer Sediment at Different Sampling Times

Parameter	Sampling Times		
	DAY 1	DAY 2	DAY 7
Benzo(b,k)-fluoranthene	3.65(2.98)	13.1(6.71)	<5.4-5.9
Benzo(a)-pyrene	8.25(6.74)	14.0(6.81)	<4.3-4.8
Benzo(g,h,i)-perylene	<4.5-10.0	6.6(1.56)	<3.5-3.8
Naphthalene	143(45.2)	50.0(1.30)	302(73.5)
Phenanthrene	85.2(34.2)	5.07(2.32)	5.67(4.09)
Fluoranthrene	6.75(5.11)	6.83(2.13)	<7.9
Pyrene	48.6(12.6)	55.7(3.71)	10.4(2.11)
Benzo(a)-anthracene	0.31(0.25)	7.34(1.65)	<5.0-5.5
Chrysene	5.1(4.2)	9.87(1.37)	4.5(0.15)
Acenaphthylene	<5.6-12.5	1.47(1.47)	<4.3-4.8
Fluorene	7.85(6.42)	6.47(3.29)	30(1.21)
Anthracene	11.5(9.40)	7.3(0.20)	<5.0-5.5
Acenaphthene	27.4(3.33)	26.3(2.92)	30(1.21)

* Expressed in nanograms per liter (standard error in parentheses).

presented in Table V-8. The pH was 1 to 2 units higher during early stages of anaerobic leaching than during aerobic leaching.

Initial conductivities of anaerobic and oxidized Oakland Inner and Outer Harbor sediments were similar (Table V-8). Conductivity decreased as leaching proceeded, reaching relatively constant values by the fifth leach cycle. This reflected a washout of salts during leaching.

Anaerobic Metal and Butyltin Releases. Steady-state metal concentrations in leachate (C) and sediment (q) from the sequential batch leaching tests for anaerobic Oakland Inner Harbor sediment are presented in Tables V-9 and V-10, respectively. Copper, chromium, and lead exhibited peak leachate concentrations in the third leach cycle, then decreased. Zinc and nickel exhibited a peak in the second and third leach cycles. Arsenic and cadmium concentrations peaked during the second leach cycle, while Hg remained relatively unchanged over the seven cycles. Butyltin concentrations generally peaked between the first and fourth leach cycles.

Steady-state metal concentrations in leachate and sediment obtained from the sequential batch leaching tests for anaerobic Oakland Outer Harbor sediment are presented in Tables V-11 and V-12, respectively. Leachate concentrations of all metals tested, except for As and Ag, peaked during the third leach cycle. Arsenic concentrations peaked in the fourth leach cycle. Ag concentrations peaked in the second leach cycle. Monobutyltin and dibutyltin concentrations peaked in the third leach cycle, while tributyltin concentrations peaked in the second leach cycle. Metal and tributyltin concentrations during sequential batch leaching of anaerobic Oakland Harbor sediment are presented in Figures V-5 through V-7 for Zn, Cu, and tributyltin, respectively.

Aerobic metal and butyltin releases. Sediment and leachate metal concentrations obtained from the sequential batch leaching tests for aerobic Oakland Inner Harbor sediment are presented in Tables V-13 and V-14, respectively. Leachate concentrations of As, Hg, monobutyltin, and tributyltin peaked in the third leach cycle. Zn, Cu, Ni, Cr, Ag, Pb, and Cd peaked at the second leach cycle. Metal concentrations in sediment and leachate for aerobic Oakland Outer Harbor sediment are presented in Tables V-15 and V-16, respectively. Steady-state leachate concentrations of Ag, Hg, and the butyltin compounds peaked in the first leach cycle, Zn, Cu, Ni, Cr, Pb, and Cd peaked in the second leach cycle, and As in the third leach cycle. Leachate concentrations of Zn, Cu, and tributyltin during sequential batch leaching of

Table v-8

Leachate pH and Conductivity (millisiemens) in Oakland Harbor

Sequential Batch Leachate Testing

Cycle	Anaerobic			Aerobic		
	pH	Conductivity	pH	Conductivity	pH	Conductivity
1	7.33(0.09)	6.57(0.16)	7.40(0.04)	4.13(0.08)	7.37(0.03)	0.61(0.01)
2	7.15(0.05)	1.70(0.03)	7.68(0.05)	0.708(0.02)	7.43(0.14)	0.14(0.01)
3	7.20(0.12)	0.54(0.01)	7.81(0.06)	0.163(0.004)	7.47(0.06)	0.09(0)
4	7.13(0.12)	0.18(0.02)	7.84(0.04)	0.094(0.001)	7.32(0.04)	0.07(0.005)
5	7.70(0.03)	0.19(0.04)	7.55(0.15)	0.08(0.005)	6.83(0.03)	0.05(0)
6	7.13(0.03)	0.10(0.003)	7.53(0.08)	0.061(0.001)	6.53(0.03)	0.06(0)
						0.74(0.01)
						0.14(0.07)
						0.06(0.002)
						0.05(0)
						0.04(0)
						0.03(0.003)

* Standard error in parentheses.

Table V-9

Heavy Metal and Butyltin Concentrations in Leachate from Anaerobic Oakland
Inner sediment in Different Leach Cycles

Parameter	Leach Cycle						
	1	2	3	4	5	6	7
As	5.58(0.48)	22.1(3.38)	18.7(1.52)	17.2(1.48)	11.7(0.72)	6.93(0.50)	5.67(0.98)
Zn	17.5(3.65)	92.0(27.3)	81.7(4.52)	36.5(2.58)	37.5(2.39)	72.6(3.35)	135(95.4)
Cu	11.3(2.13)	44.8(2.73)	59.5(3.39)	24.0(3.08)	16.3(0.78)	19.4(1.44)	21.5(7.69)
Ni	16.0(2.91)	40.1(17.0)	38.6(1.87)	13.6(0.78)	7.86(0.35)	13.9(0.64)	22.4(13.2)
Cr	2.63(1.15)	7.26(0.53)	28.3(2.46)	10.4(0.71)	6.48(0.59)	11.5(0.40)	9.02(0.61)
Ag	0.88(0.10)	0.69(0.10)	0.52(0.13)	0.41(0.01)	0.47(0.09)	0.38(0.03)	0.55(0.12)
Pb	0.74(0.23)	4.10(0.84)	19.3(1.85)	7.73(0.52)	5.05(0.21)	9.10(0.48)	9.99(3.32)
Cd	0.37(0.05)	0.85(0.20)	0.16(0.07)	<1.00	<1.00	<1.00	0.10(0.10)
Hg	0.02(0.01)	0.01(0)	0.01(0)	0.01(.01)	0.01(0)	<1.00	0.01(0)
Monobutyltin	3.97(3.97)	1.27(1.27)	2.4(1.21)	5.8(2.13)	4.4(0.87)	4.13(0.51)	NT***
Dibutyltin	11.5(11.6)	32.8(25.3)	33.5(27.2)	3.43(3.44)	2.3(1.16)	1.07(0.55)	NT***
Tributyltin	13.0(11.9)	9.67(1.09)	12.8(3.63)	9.6(0.64)	11.2(1.89)	11.2(3.79)	NT***

* Expressed in micrograms per liter (standard error in parentheses).

** Expressed in nanograms per liter (standard error in parentheses).

*** Not tested.

Table V-10

Heavy Metal* and Butyltin** Sediment Concentrations in Anaerobic Oakland Inner
in Different Leach Cycles

Parameter	Leach Cycle						
	1	2	3	4	5	6	7
As	5.60(0.002)	5.57(0.01)	5.43(0.02)	5.37(0.02)	5.32(0.02)	5.29(0.02)	5.27(0.02)
Zn	61.0(0.02)	60.7(.11)	60.3(0.12)	60.2(0.12)	60.0(0.11)	59.8(0.13)	59.2(0.51)
Cu	24.5(0.01)	24.3(0.01)	24.1(0.02)	24.0(0.01)	23.9(0)	23.8(0.10)	23.7(0.04)
Ni	65.0(0.01)	65.0(0.06)	64.8(0.06)	64.8(0.06)	64.7(0.06)	64.7(0.06)	64.6(0.07)
Cr	381.2(0)	381.2(0)	381.1(0.01)	381.1(0.01)	381.0(0.01)	381.0(0.01)	381.1(0.01)
Ag	0.11(0)	0.10(0)	0.10(0)	0.10(0)	0.10(0)	0.10(0)	0.09(0)
Pb	14.1(0)	14.1(0.10)	14.0(0.01)	14.0(0.01)	14.0(0.01)	14.0(0.01)	13.0(0.02)
Cd	0.146(0.19)	0.143(0.66)	0.142(0.68)	0.142(0.68)	0.142(0.68)	0.142(0.68)	0.142(0.43)
Hg	0.11(0)	0.11(0)	0.11(0)	0.11(0)	0.11(0)	0.11(0)	0.11(0)
Monobutyltin	0.18(0.02)	0.18(0.01)	0.17(0.02)	0.15(0.02)	0.13(0.03)	0.11(0.03)	NT***
Dibutyltin	4.49(.005)	4.36(0.08)	4.22(0.13)	4.21(0.14)	4.20(0.14)	4.19(0.14)	NT***
Tributyltin	5.01(0.05)	4.98(0.05)	4.92(0.06)	4.89(0.06)	4.84(0.06)	4.80(0.08)	NT***
Tetrabutyltin							

-- Not Detected in Sediment (<1.6-3.6) --

* Expressed in milligrams per kilogram (standard error in parentheses).

** Expressed in micrograms per kilogram (standard error in parentheses).

*** Not tested.

Table V-11

Heavy Metal* and Butyltin** Concentrations in Leachate from Anaerobic Oakland Harbor Outer
Sediment in Different Leach Cycle

Parameter	Leach Cycle						
	1	2	3	4	5	6	7
As	29.5(0.80)	20.9(1.91)	31.5(2.62)	40.1(1.10)	28.4(1.45)	8.91(3.72)	<0.94
Zn	16.5(4.77)	46.6(3.01)	162(29.9)	53.1(5.19)	63.2(9.57)	60.9(18.0)	20.9(2.75)
Cu	9.78(3.76)	50.6(5.34)	249(78.3)	77.0(12.1)	31.5(0.54)	36.6(12.8)	10.9(1.26)
Ni	21.8(5.61)	23.1(7.05)	75.5(14.5)	25.7(2.53)	17.0(0.52)	18.5(6.06)	6.96(2.63)
Cr	3.04(0.08)	9.76(1.13)	60.7(16.0)	20.6(2.82)	13.3(0.14)	17.4(6.01)	4.83(3.15)
Ag	0.42(0.04)	0.48(0.11)	0.28(0.02)	0.30(0.05)	0.25(0.01)	0.29(0.03)	0.31(0.07)
Pb	1.39(0.71)	24.9(3.79)	89.6(31.1)	22.0(3.39)	14.1(0.50)	20.2(7.87)	4.60(2.72)
Cd	0.15(0.01)	0.51(0.05)	1.04(0.24)	0.31(0.08)	0.30(0.04)	0.37(0.09)	0.24(0.03)
Hg	0.47(0.01)	<0.01	0.07(0.12)	0.03(0)	0.03(0.01)	0.03(0.01)	<0.01
Monobutyltin	1.67(0.85)	1.03(1.04)	6.43(5.24)	2.7(1.27)	<215.1	4.13(3.94)	NT***
Dibutyltin	0.5(0.45)	4.93(4.94)	28.1(24.2)	5.9(5.46)	4.8(1.74)	11.3(2.66)	NT***
Tributyltin	1.33(0.67)	25.4(6.00)	16.7(4.56)	16.5(1.92)	1.67(1.57)	2.93(0.93)	NT***

* Expressed in micrograms per liter (standard error in parentheses).

** Expressed in nanograms per liter (standard error in parentheses).

*** Not tested.

Table V-12

Heavy Metal* and Butyltin** Sediment Concentrations in Anaerobic Oakland
Outer in Different Leach Cycles

Parameter	Leach Cycle						
	1	2	3	4	5	6	7
As	6.78(0)	6.70(0.01)	6.57(0.02)	6.41(0.02)	6.30(0.02)	6.26(0.04)	6.26(0.04)
Zn	84.7(0.02)	84.6(0.03)	83.9(0.10)	83.7(0.10)	83.4(0.14)	83.2(0.19)	83.1(0.18)
Cu	31.0(0.02)	30.8(0.01)	30.0(0.32)	29.5(0.31)	29.4(0.31)	29.3(0.36)	29.2(0.36)
Ni	84.0(0.02)	83.9(0.02)	83.6(0.07)	83.5(0.07)	83.4(0.06)	83.3(0.08)	83.3(0.07)
Cr	364.0(0)	364.0(0)	363.7(0.01)	363.6(0.01)	363.6(0.06)	363.5(0.08)	363.5(0.07)
Ag	0.20(0)	0.20(0)	0.20(0)	0.20(0)	0.20(0)	0.20(0)	0.20(0)
Pb	18.7(0)	18.6(0.01)	18.2(0.14)	18.1(0.13)	18.1(0.13)	18.0(0.16)	18.0(0.15)
Cd	0.23(0)	0.23(0)	0.23(0)	0.23(0)	0.22(0)	0.22(0)	0.22(0)
Hg	0.17(0)	0.17(0)	0.17(0)	0.17(0)	0.17(0)	0.17(0)	0.17(0)
Monobutyltin	0.83(0)	0.82(0)	0.80(0.02)	0.79(0.02)	0.79(0.02)	0.77(0.02)	NT***
Dibutyltin	2.50(0)	2.48(0)	2.37(0.09)	2.34(0.07)	2.32(0.07)	2.28(0.06)	NT***
Tributyltin	2.86(0)	2.76(0.02)	2.69(0.02)	2.63(0.02)	2.62(0.03)	2.61(0.03)	NT***
Tetrabutyltin			-- Not Detected in Sediment (<1.1-3.5)	--			

* Expressed in milligrams per kilogram (standard error in parentheses).

** Expressed in micrograms per kilogram (standard error in parentheses).

*** Not tested.

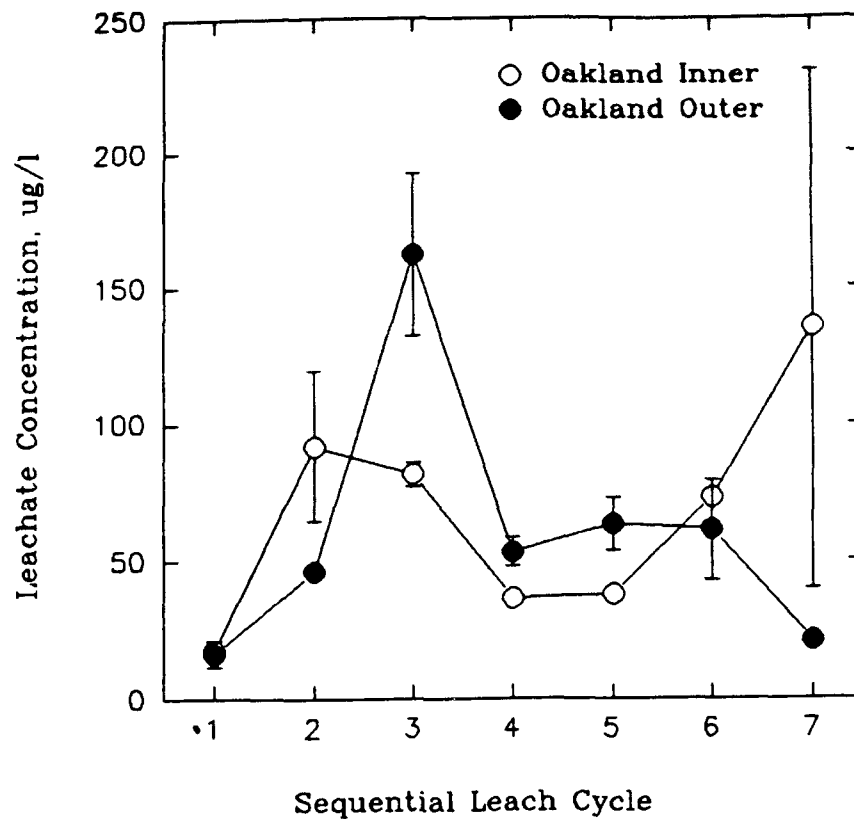


Figure V-5. Zinc Concentrations in Oakland Harbor Sequential Batch Leachate

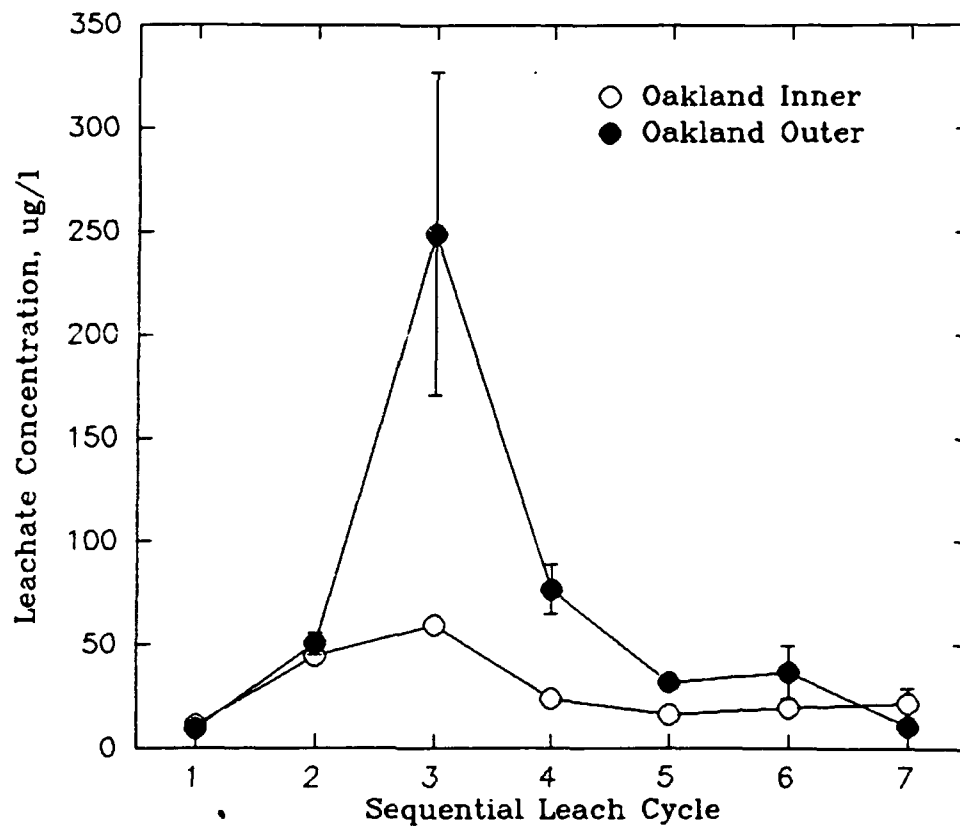


Figure V-6. Copper Concentrations in Oakland Harbor Sequential Batch Leachate

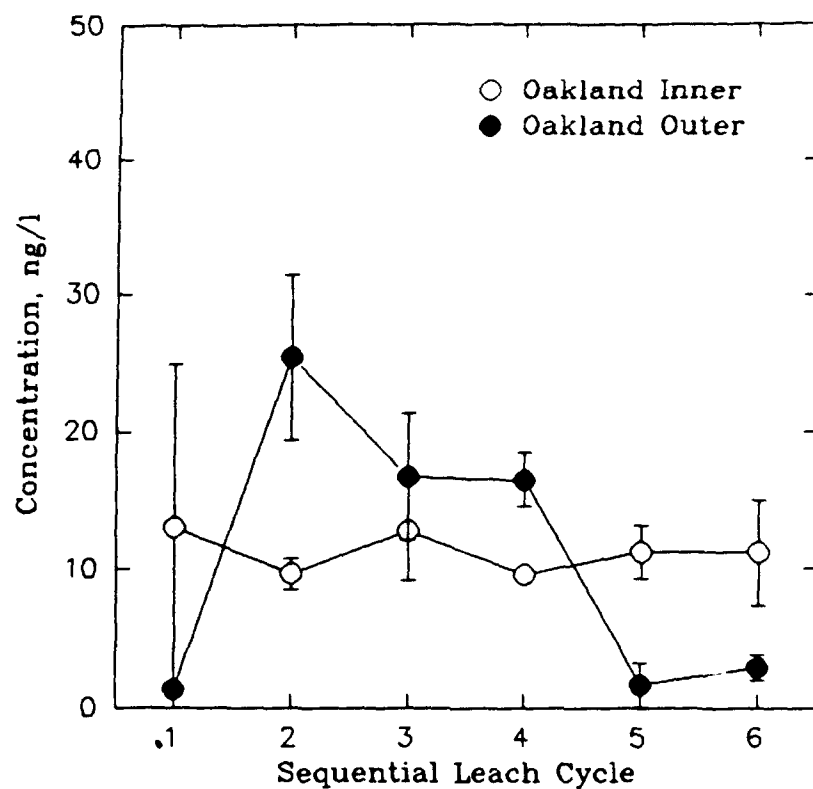


Figure V-7. Tributyltin Concentrations in Oakland Harbor Sequential Batch Leachate

Table V-13

Heavy Metal* and Butyltin** Concentrations in Leachate from Aerobic Oakland Harbor Inner
Sediment in Different Leach Cycles

Parameter	Leach Cycle						
	1	2	3	4	5	6	7
As	3.93(0.39)	20.1(8.86)	29.6(5.17)	20.9(3.13)	10.8(1.45)	13.6(0.71)	14.5(1.02)
Zn	8.17(0.78)	227(79.9)	48.4(2.47)	61.2(9.83)	53.7(10.3)	37.6(7.89)	50.2(8.73)
Cu	15.3(0.67)	142.8(60.0)	35.4(2.83)	36.3(1.42)	29.2(7.73)	31.8(15.4)	32.6(1.86)
Ni	4.70(0.21)	99.4(32.0)	27.6(1.92)	26.6(1.24)	24.6(6.25)	14.1(1.59)	31.0(1.25)
Cr	2.90(0.06)	96.3(39.1)	27.4(2.79)	24.6(0.53)	23.5(6.54)	11.6(0.70)	27.1(0.20)
Ag	0.75(0.36)	1.27(0.13)	1.20(0.02)	1.16(0.02)	1.17(0.02)	1.27(0.10)	1.16(0.01)
Pb	2.91(0.10)	82.8(34.9)	17.6(1.25)	20.6(0.44)	17.8(5.44)	10.1(2.20)	14.4(0.89)
Cd	0.02(0.01)	0.02(0.01)	0.08(0.06)	0.01(0)	0.03(0.02)	0.01(0.01)	0.01(0)
Hg	0.02(0.01)	0.02(0.01)	0.08(0.06)	0.01(0)	0.03(0.02)	0.01(0.01)	0.01(0)
Monobutyltin	4.64(0.89)	5.30(1.23)	6.70(2.94)	2.48(1.53)	5.95(4.01)	0.29(0.29)	NT***
Dibutyltin	26.6(9.91)	10.8(1.52)	18.6(9.53)	6.47(1.07)	9.07(1.84)	4.10(2.20)	NT***
Tributyltin	7.03(1.89)	4.97(1.36)	17.4(8.43)	2.67(1.35)	3.27(1.76)	2.0(2.0)	NT***

* Expressed in micrograms per liter (standard error in parentheses).

** Expressed in nanograms per liter (standard error in parentheses).

*** Not tested.

Table V-14

Heavy Metal* and Butyltin** Sediment Concentrations in Aerobic
Oakland Inner in Different Leach Cycles

Parameter	Leach Cycle						
	1	2	3	4	5	6	7
As	5.60(0)	5.52(0.04)	5.41(0.05)	5.32(0.07)	5.28(0.07)	5.22(0.07)	5.17(0.07)
Zn	61.1(0)	60.2(0.32)	60.0(0.33)	59.7(0.37)	59.5(0.37)	59.4(0.34)	59.1(0.38)
Cu	24.5(0)	23.9(0.24)	23.8(0.25)	23.6(0.26)	23.5(0.27)	23.4(0.26)	23.2(0.25)
Ni	65.2(0)	64.8(0.13)	64.7(0.13)	64.6(0.13)	64.5(0.13)	64.4(0.13)	64.3(0.13)
Cr	381.2(0)	380.9(0.16)	380.7(0.17)	380.7(0.17)	380.6(0.17)	380.5(0.17)	380.4(0.17)
Ag	0.107(0)	0.102(0)	0.097(0)	0.092(0)	0.088(0)	0.083(0)	0.078(0)
Pb	14.1(0)	13.8(0.14)	13.7(0.14)	13.7(0.15)	13.6(0.15)	13.5(0.15)	13.5(0.15)
Cd	0.147(0)	0.110(0)	0.109(0)	0.109(0)	0.109(0)	0.109(0)	0.109(0)
Hg	0.110(0)	0.110(0)	0.109(0)	0.109(0)	0.109(0)	0.109(0)	0.109(0)
Monobutyltin	-- Not Detected in Sediment (<5.1) --						
Dibutyltin	3.99(0.04)	3.95(0.23)	3.88(0.23)	3.85(0.02)	3.81(0.02)	3.80(0.02)	NT***
Tributyltin	-- Not Detected in Sediment (<2.0) --						

* Expressed in milligrams per kilogram (standard error in parentheses).

** Expressed in micrograms per kilogram (standard error in parentheses).

*** Not tested.

Table V-15
Heavy Metal* and Butyltin** Concentrations in Leachate from Aerobic Oakland Harbor Outer
Sediment in Different Leach Cycles

Parameter	Leach Cycle						
	1	2	3	4	5	6	7
As	21.6(6.68)	30.4(10.9)	45.7(1.22)	31.9(3.27)	27.0(1.24)	22.0(2.36)	18.7(4.87)
Zn	136.5(116)	196.7(67.6)	90.5(21.9)	128.7(13.1)	70.4(21.9)	42.0(14.1)	64.3(33.8)
Cu	115.9(52.2)	137.5(45.0)	73.3(11.7)	80.4(9.96)	43.7(11.0)	28.9(9.75)	32.7(15.8)
Ni	53.8(40.1)	85.9(26.7)	40.9(8.22)	48.7(15.3)	27.4(8.18)	17.0(6.10)	22.2(12.5)
Cr	54.3(44.9)	83.0(23.8)	43.8(9.35)	52.5(6.08)	28.4(8.90)	16.4(6.82)	24.0(12.9)
Ag	1.45(0.02)	1.38(0.05)	1.32(0.02)	1.30(0.03)	1.29(0.07)	1.21(0.01)	1.73(0.40)
Pb	54.7(44.7)	81.3(26.4)	44.2(9.64)	56.3(9.20)	29.2(9.08)	17.8(7.13)	19.1(9.42)
Cd	1.07(0.76)	1.50(0.69)	0.54(0.13)	0.91(0.06)	0.46(0.15)	0.38(0.16)	0.49(0.23)
Hg	0.051(0.01)	0.026(0.01)	0.019(0)	0.013(0)	0.011(0)	0.005(0)	0.01(0)
Monobutyltin	16.0(5.93)	15.4(6.75)	10.6(2.71)	2.31(1.81)	8.11(4.89)	9.64(0.69)	NT***
Dibutyltin	31.5(0.68)	30.4(1.74)	21.3(5.67)	11.0(1.27)	15.0(4.21)	8.00(2.50)	NT***
Tributyltin	50.8(4.51)	42.8(3.65)	27.6(5.53)	15.7(4.03)	12.3(1.21)	12.7(3.75)	NT***

* Expressed in micrograms per liter (standard error in parentheses).
 ** Expressed in nanograms per liter (standard error in parentheses).
 *** Not tested.

Table V-16

Heavy Metal* and Butyltin** Sediment Concentrations in Aerobic
Oakland Outer in Different Leach Cycles

Parameter	Leach Cycle						
	1	2	3	4	5	6	7
As	6.81(0.03)	6.69(0.07)	6.51(0.07)	6.38(0.09)	6.27(0.08)	6.19(0.08)	6.11(0.08)
Zn	84.3(0.46)	83.5(0.24)	83.1(0.32)	82.6(0.26)	82.3(0.20)	82.1(0.25)	81.9(0.19)
Cu	30.6(0.21)	30.1(0.21)	29.8(0.13)	29.4(0.10)	29.3(0.08)	29.2(0.10)	29.0(0.10)
Ni	83.8(0.16)	83.5(0.06)	83.3(0.09)	83.1(0.03)	83.0(0.01)	82.9(0.02)	82.9(0.04)
Cr	363.8(0.18)	363.5(0.09)	363.3(0.13)	363.1(0.11)	363.0(0.08)	363.0(0.10)	362.8(0.08)
Ag	0.198(0)	0.192(0)	0.187(0)	0.182(0)	0.176(0)	0.172(0)	0.165(0)
Pb	18.5(0.18)	18.1(0.10)	18.0(0.13)	17.7(0.10)	17.6(0.07)	17.5(0.10)	17.5(0.07)
Cd	0.229(0)	0.223(0)	0.221(0)	0.217(0)	0.215(0)	0.214(0)	0.212(0)
Hg	0.1658(0)	0.1657(0)	0.1656(0)	0.1656(0)	0.1655(0)	0.1655(0)	0.1655(0)
Monobutyltin	-- Not Detected in Sediment (<5.1) --						
Dibutyltin	-- Not Detected in Sediment (1.4-2.1) --						
Tributyltin	2.50(0.02)	2.33(0.03)	2.22(0.03)	2.15(0.03)	2.10(0.02)	2.05(0.03)	NT***

* Expressed in milligrams per kilogram (standard error in parentheses).

** Expressed in micrograms per kilogram (standard error in parentheses).

*** Not tested.

aerobic Oakland Harbor sediments are presented in Figure V-8. The peaks in leachate concentration described in the preceding discussion of aerobic sequential batch leaching of metals, are evident in these data.

Anaerobic PAH releases. Steady-state PAH concentrations in leachate (C) and sediment (q) obtained from the sequential batch leaching tests for anaerobic Oakland Inner Harbor sediment are presented in Tables V-17 and V-18, respectively. Leachate concentrations of PAH compounds generally peaked during the third leach cycle, but chrysene peaked during the second leach cycle. Benzo(k)-fluoranthene, phenanthrene, and chrysene also exhibited concentration peaks following the peak in the third leach cycle.

Steady-state PAH concentrations in leachate and sediment obtained from the sequential batch leaching tests for anaerobic Oakland Outer Harbor sediment are presented in Tables V-19 and V-20, respectively. Leachate concentrations of PAH compounds generally peaked during the fourth leach cycle. Benzo(b,k)-fluoranthene, fluoranthene, and pyrene also exhibited concentration peaks following the concentration peak in the fourth leach cycle. PAH concentrations during sequential batch leaching of anaerobic Oakland Harbor sediment are presented in Figure V-9 for pyrene. The peak in leachate concentration during sequential leaching for PAHs, described in the preceding discussion of sequential batch leaching of PAH, are evident in these data. Leaching patterns for PAHs from Oakland Inner and Outer Harbor sediments were similar to those observed for PCBs during sequential leaching from other saline sediments (Brannon et al. 1991).

Aerobic PAH releases. Steady-state PAH concentrations in leachate (C) and sediment (q) obtained from the sequential batch leaching tests for aerobic Oakland Inner Harbor sediment are presented in Tables V-21 and V-22, respectively. Leachate PAH compounds were generally present in trace concentrations and showed little change during the course of leaching.

Steady-state PAH concentrations in leachate and sediment obtained from the sequential batch leaching tests for anaerobic Oakland Outer Harbor sediment are presented in Tables V-23 and V-24, respectively. As was the case for aerobic Oakland Inner Harbor sediment, leachate concentrations of PAH compounds were generally present in trace concentrations and showed little change

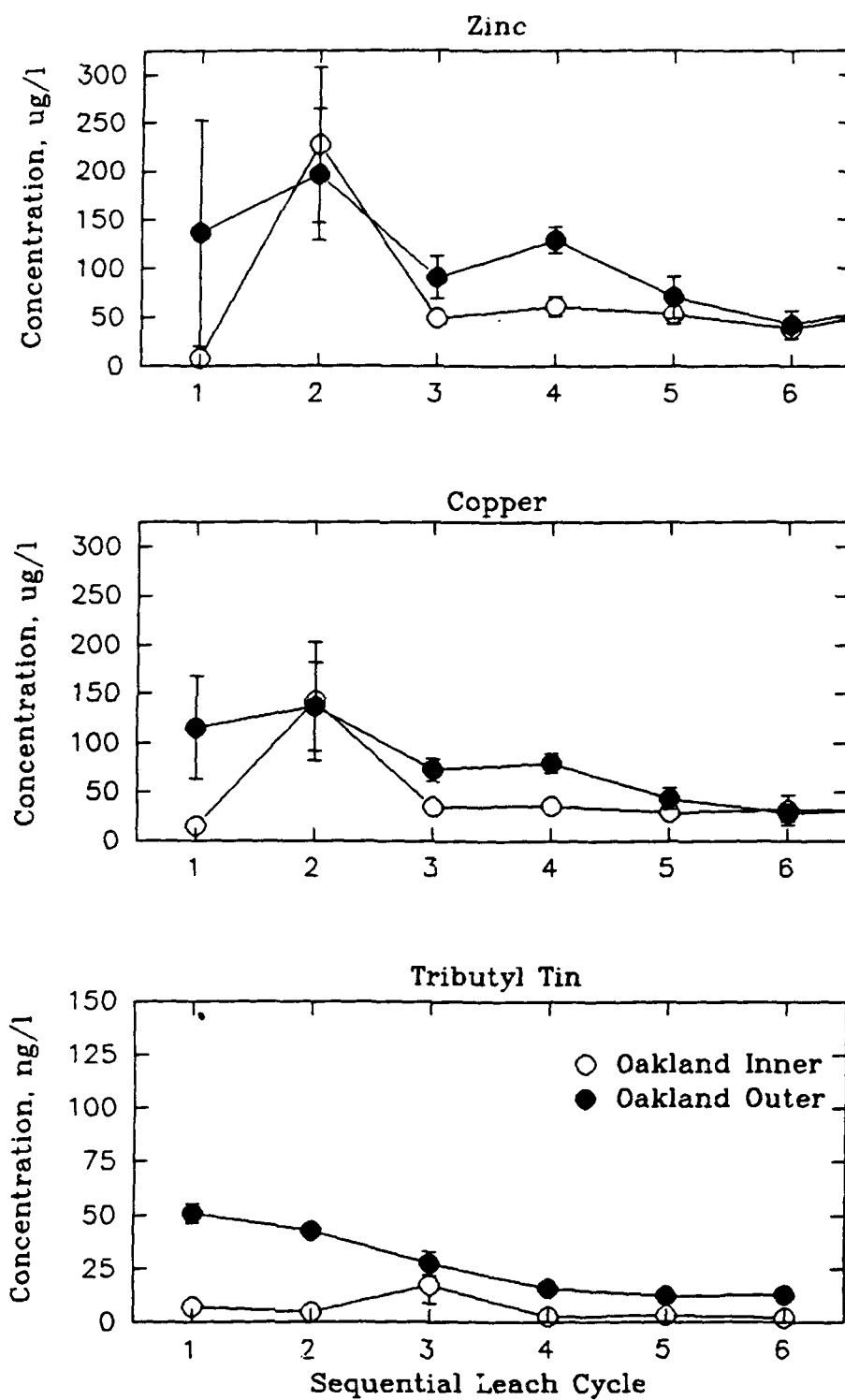


Figure V-8. Zinc, Copper, and Tributyltin Concentrations in Oakland Harbor Aerobic Sequential Batch Leachate

Table V-17

PAH Concentrations* in Leachate from Anaerobic Oakland Inner
Sediment in Different Leach Cycles

Parameter	Leach Cycle					
	1	2	3	4	5	6
Benzo(b,k)-fluoranthene	<13.4-33.3	62.6(3.02)	125(36.9)	92.3(6.80)	104(5.35)	159(42.6)
Benzo(a)-pyrene	<8.9-11.3	28.7(7.02)	92.7(22.9)	68.6(5.64)	72.9(7.10)	74.0(13.9)
Indeno(1,2,3-c,d)-pyrene	<8.9-22.2	13.3(1.28)	26.8(7.78)	17.8(2.97)	23.8(3.96)	12.8(7.37)
Benzo(g,h,i)-perylene	<8.9-22.2	21.1(2.20)	34.6(6.71)	22.6(3.58)	28.4(1.42)	27.8(5.24)
Naphthalene	36.2(3.55)	35.8(1.63)	43.9(5.32)	29.9(6.74)	25.0(4.13)	17.7(0.79)
Phenanthrene	18.2(3.39)	25.6(1.56)	57.9(5.58)	35.0(0.79)	63.7(28.2)	45.2(1.45)
Fluoranthrene	8.77(4.47)	31(1.61)	87.2(22.5)	68.3(4.86)	72.6(15.7)	79.3(7.72)
Pyrene	56.0(10.9)	124(3.79)	332(97.2)	238(16.3)	177(17.7)	236(26.4)
Benzo(a)-anthracene	<8.9-22.2	7.7(3.88)	23.7(7.13)	21.1(1.75)	26.0(1.78)	27.3(2.30)
Chrysene	<8.9-22.2	18.1(5.15)	14.8(9.51)	10.7(5.43)	24.0(5.94)	33.4(3.25)
Acenaphthylene	<8.9-22.2	<9.9-11.6	9.1(4.83)	<11.8-15.2	6.4(6.41)	<11.8-16.0
Fluorene	<8.9-22.2	<9.9-11.6	5.3(5.31)	<11.8-15.2	5.37(5.37)	<11.8-16.0
Anthracene	<8.9-22.2	<9.9-11.6	10.8(5.97)	<11.8-15.2	<12.3-14.7	<11.8-16.0

* Expressed in nanograms per liter (standard error in parentheses).

Table V-18

PAH Sediment Concentrations* in Anaerobic Oakland Inner
in Different Leach Cycle

Parameter	Leach Cycle					
	1	2	3	4	5	6
Benzo(b,k)-fluoranthene	152.7(0)	152.4(0.01)	151.9(0.14)	151.6(0.11)	151.1(0.09)	150.5(0.19)
Benzo(a)-pyrene	110.0(0)	109.9(0.03)	109.5(0.10)	109.2(0.08)	109.0(0.07)	108.7(0.05)
Indeno(1,2,3-c,d)-pyrene	86.0(0)	86.0(0.01)	85.8(0.03)	85.8(0.02)	85.7(0.01)	85.6(0.03)
Benzo(g,h,i)-perylene	109.3(0)	109.2(0.01)	109.1(0.03)	109.0(0.02)	108.9(0.01)	108.8(0.02)
Naphthalene	7.85(0.01)	7.71(0.01)	7.54(0.03)	7.42(0.05)	7.32(0.05)	7.25(0.05)
Phenanthrene	24.3(0.01)	24.2(0.01)	23.9(0.03)	23.8(0.03)	23.5(0.09)	23.4(0.09)
Fluoranthene	71.0(0.02)	70.8(0.02)	70.5(0.07)	70.2(0.05)	69.9(0.06)	69.6(0.09)
Pyrene	123.1(0.04)	122.6(0.06)	121.3(0.43)	120.3(0.38)	119.6(0.31)	118.7(0.29)
Benzo(a)-anthracene	41.7(0)	41.6(0.02)	41.5(0.03)	41.5(0.03)	41.4(0.03)	41.2(0.03)
Chrysene	45.0(0)	44.9(0.02)	44.9(0.03)	44.8(0.04)	44.7(0.04)	44.6(0.06)
Acenaphthylene	3.33(0)	3.33(0)	3.30(0.02)	3.30(0.02)	3.27(0.04)	3.27(0.04)
Fluorene	3.00(0)	3.00(0)	2.98(0.02)	2.98(0.02)	2.96(0.02)	2.96(0.02)
Anthracene	7.00(0)	7.00(0)	6.96(0.02)	6.96(0.02)	6.96(0.02)	6.96(0.02)
Acenaphthene	5.0(0)	5.0(0)	4.96(0.02)	4.96(0.02)	4.94(0.03)	4.94(0.03)

* Expressed in micrograms per kilogram (standard error in parentheses).

Table V-19

PAH Concentrations* in Leachate from Anaerobic Oakland Harbor Outer
Sediment in Different Leach Cycles

Parameter	Leach Cycle					
	1	2	3	4	5	6
Benzo(b, k) - fluoranthene	<13.4-13.9	16.4(16.5)	90.4(34.9)	141(29.9)	60.3(7.46)	157(43.5)
Benzo(a) - pyrene	<9.0-9.3	9.13(9.14)	<11.3-12.7	66.8(13.5)	32.4(4.98)	49.3(12.7)
Indeno-(1,2,3-c,d)pyrene	<9.0-9.3	<9.2-21.7	5.13(5.14)	31.0(7.02)	<12.6-13.5	8.23(8.24)
Benzo(g, h, i) - perylene	<9.0-9.3	<9.2-21.7	<11.3-12.7	52.3(11.9)	14.7(7.38)	46.1(17.5)
Naphthalene	25.3(1.76)	24.8(6.43)	16.7(1.04)	43.8(4.56)	16.8(1.80)	17.2(9.51)
Phenanthrene	40.0(2.23)	24.8(11.9)	22.1(6.23)	40(9.88)	22.4(4.91)	21.1(11.6)
Fluoranthrene	18.7(1.10)	28.1(11.9)	63.7(25.9)	93.7(24.6)	53.5(8.36)	109(18.0)
Pyrene	36.5(2.84)	59.9(24.2)	18.4(11.1)	265(63.2)	144(20.0)	291(49.8)
Benzo(a) - anthracene	<9.0-9.3	<17.8-37.6	<11.8-12.7	29.9(5.68)	12.8(6.65)	33(5.73)
Chrysene	<9.0-9.3	6.3(6.31)	16.7(1.04)	43.8(4.56)	16.8(1.80)	17.2(9.51)

* Expressed in nanograms per liter (standard error in parentheses).

Table V-20

PAH Sediment Concentrations* in Anaerobic Oakland Outer
in Different Leach Cycles

Parameter	Leach Cycle					
	1	2	3	4	5	6
Benzo(b,k) - fluoranthene	132.0(0)	131.9(0.07)	131.6(0.15)	131.0(0.08)	130.8(0.11)	130.1(0.26)
Benzo(a) - pyrene	92.0(0)	92.0(0.04)	92.0(0.04)	91.7(0.09)	91.6(0.11)	91.4(0.16)
Indeno-(1,2,3-c,d)pyrene	91.6(0)	91.6(0)	91.6(0.02)	91.5(0.01)	91.5(0.01)	91.4(0.03)
Benzo(g,h,i) - perylene	119.6(0)	119.6(0)	119.6(0)	119.4(0.05)	119.3(0.08)	119.2(0.14)
Naphthalene	7.90(0.07)	7.80(0.03)	7.73(0.03)	7.56(0.05)	7.49(0.05)	7.42(0.02)
Phenanthrene	23.4(0.09)	23.3(0.05)	23.3(0.05)	23.1(0.04)	23.0(0.05)	22.9(0.01)
Fluoranthrene	49.9(0.04)	49.8(0.05)	49.6(0.12)	49.2(0.04)	49.0(0.07)	48.5(0.11)
Pyrene	83.9(0.11)	83.6(0.11)	83.5(0.12)	82.5(0.23)	81.9(0.29)	80.7(0.49)
Benzo(a) - anthracene	40.0(0)	40.0(0)	40.0(0)	39.9(0.02)	39.8(0.05)	39.7(0.07)
Chrysene	50.3(0)	50.3(0.03)	50.2(0.02)	50.0(0.02)	50.0(0.01)	49.9(0.04)

* Expressed in micrograms per kilogram (standard error in parentheses).

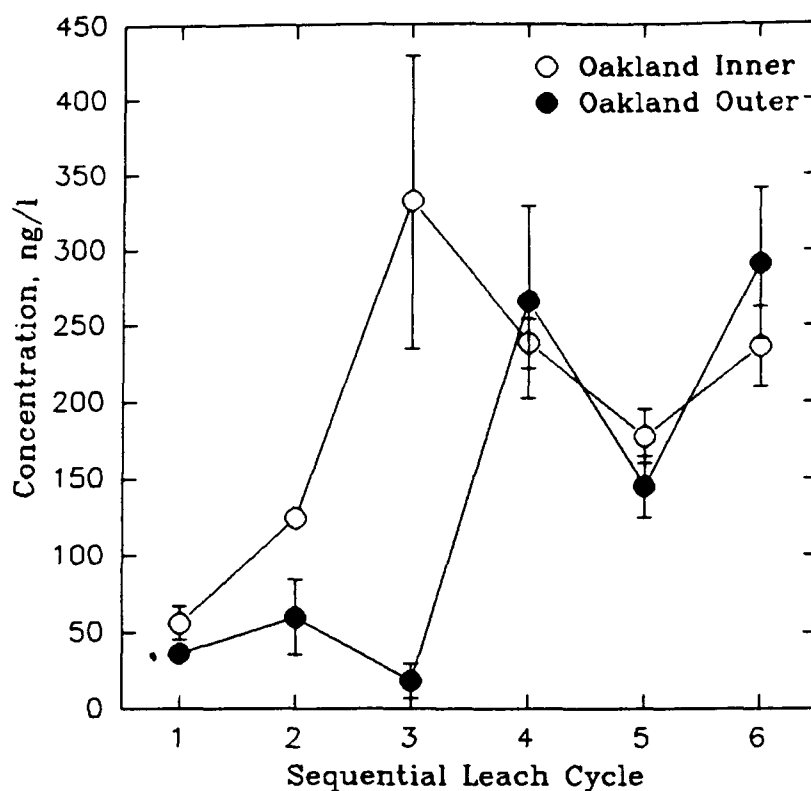


Figure V-9. Pyrene Concentrations in Anaerobic Oakland Harbor Sequential Batch Leachate

during the course of leaching. PAH concentrations during sequential batch leaching of aerobic Oakland Harbor sediment are presented in Figure V-10 for pyrene. Leaching patterns for PAHs from Oakland Inner and Outer Harbor sediments were similar to those observed for PCBs during sequential leaching from other saline sediments (Brannon et al. 1991).

Cumulative and percentage losses of metals and butyltin during leaching.

Cumulative net mass releases of metals from Oakland Inner and Outer Harbor sediments were generally similar between sediments, except for As, Ag, Pb, and Cd which showed substantially less release from Oakland Outer Harbor sediment (Table V-25). However, larger releases of the butyltin compounds were observed from Oakland Outer Harbor sediment under anaerobic conditions. Cumulative net mass metal releases following leaching of aerobic sediment were either similar to or higher than releases from anaerobic sediment. No losses of some butyltin compounds were observed under aerobic conditions because the compounds were not detected in the sediment following six months of aerobic incubation.

Table V-21

PAH Concentrations* in Leachate from Aerobic Oakland Harbor Inner

Sediment in Different Leach Cycles

Parameter	Leach Cycles					
	1	2	3	4	5	6
Naphthalene	25.2(1.27)	31.2(2.01)	33.9(4.76)	31.0(6.18)	40.2(1.95)	48.3(3.70)
Phenanthrene	5.28(0.61)J**	3.58(0.22)J**	5.25(0.49)J**	6.53(0.53)J**	5.64(1.84)J**	2.85(1.42)J**
Fluoranthrene	4.96(0.72)J**	2.42(0.15)J**	2.69(0.43)J**	3.56(0.47)J**	2.24(0.27)J**	3.21(0.49)J**
Pyrene	15.2(1.71)	8.12(0.97)	7.70(1.58)	10.4(1.87)	4.80(0.36)J**	6.24(0.96)
Acenaphthylene	<9.17	0.96(0.96)	1.87(0.94)	3.57(0.17)	<9.17	<9.17
Fluorene	2.66(0.14)J**	2.14(0.17)J**	3.66(0.15)J**	4.94(0.44)J**	2.90(0.19)J**	2.90(0.21)J**
Acenaphthene	<5.87	<5.87	<5.87	4.75(0.48)	4.10(0.67)	4.74(0.24)

* Expressed in nanograms per liter (standard error in parentheses).

** Value below method detection limit (present in trace amounts).

Table V-22

PAH Concentrations* in Leachate from Aerobic Oakland Harbor Outer

Sediment in Different Leach Cycles

Parameter	Leach Cycles					
	1	2	3	4	5	6
Benzo(b,k)-fluoranthene	12.85(4.95)J**	2.79(1.46)J**	<28.01	<28.01	<28.01	<28.01
Benzo(a)-pyrene	3.18(1.55)J**	0.52(0.52)J**	<6.39	<6.39	<6.39	<6.39
Naphthalene	35.5(2.05)	35.9(2.62)	47.0(12.2)	58.7(12.2)	40.6(6.15)	7.4(3.18)
Phenanthrene	5.82(1.28)J**	5.32(1.01)J**	4.97(0.42)J**	3.90(0.11)J**	5.39(0.84)J**	4.43(0.76)J**
Fluoranthrene	9.32(2.84)	4.23(0.63)J**	2.88(0.33)J**	2.48(0.15)J**	2.41(1.22)J**	3.13(0.37)J**
Pyrene	24.7(7.84)	9.0(1.21)	4.80(0.69)J**	4.47(0.35)J**	5.0(0.22)J**	3.82(0.49)J**
Benzo(a)-anthracene	3.03(1.0)J**	1.19(0.60)J**	<30.2	<30.2	<30.2	<30.2
Chrysene	3.37(1.36)J**	0.89(0.50)J**	<19.2	<19.2	<19.2	<19.2
Fluorene	3.63(0.43)J**	3.62(0.72)J**	1.82(0.95)J**	3.10(0.08)J**	2.86(1.44)J**	3.62(0.43)J**
Acenaphthene	3.47(0.32)J**	3.03(0.51)J**	1.16(0.60)J**	1.70(0.94)J**	2.07(1.06)J**	2.43(0.11)J**

* Expressed in nanograms per liter (standard error in parentheses).

** Value below method detection limit (present in trace amounts).

Table V-23

PAH Sediment Concentrations* in Aerobic Oakland Inner
in Different Leach Cycles

<u>Parameter</u>	<u>Leach Cycles</u>					
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
Phenanthrene	19.7(0.002)	19.7(0.002)	19.6(0.004)	19.6(0.002)	19.6(0.008)	19.6(0.012)
Fluoranthrene	72.2(0.003)	72.2(0.003)	72.2(0.002)	72.2(0.002)	72.1(0.003)	72.1(0.005)
Pyrene	143.4(0.01)	143.4(0.01)	143.4(0.01)	143.3(0.01)	143.3(0.01)	143.2(0.01)
Benzo(a) -anthracene	21.9(0)	21.0(0)	21.0(0)	21.0(0.001)	21.0(0.001)	21.0(0.001)
Chrysene	30.3(0)	30.3(0)	30.3(0)	30.3(0.002)	30.3(0.002)	30.3(0.002)

* Expressed in micrograms per kilogram (standard error in parentheses).

Table V-24

PAH Sediment Concentrations* in Aerobic Oakland Outer

in Different Leach Cycles

Parameter	Leach Cycles					
	1	2	3	4	5	6
Benzo(b,k)-fluoranthene	86.0(0.01)	86.0(0.01)	86.0(0.01)	86.0(0.01)	86.0(0.01)	86.0(0.01)
Benzo(a)-pyrene	53.8(0.01)	53.8(0.01)	53.8(0.01)	53.8(0.01)	53.8(0.01)	53.8(0.01)
Indeno-(1,2,3-c,d)pyrene	24.4(0.01)	24.4(0.01)	24.4(0.01)	24.4(0.01)	24.4(0.01)	24.4(0.01)
Benzo(g,h,i)-perylene	18.2(0.01)J**	18.2(0.01)	18.2(0.01)	18.2(0.01)	18.2(0.01)	18.2(0.01)
Phenanthrene	20.3(0.01)	20.3(0.003)	20.2(0.004)	20.2(0.003)	20.2(0.01)	20.2(0.01)
Fluoranthrene	58.6(0.01)	58.6(0.01)	58.5(0.01)	58.5(0.01)	58.5(0.004)	58.5(0.01)
Pyrene	105.0(0.031)	105.0(0.028)	105.0(0.028)	104.9(0.027)	104.9(0.026)	104.9(0.026)
Benzo(a)-anthracene	25.0(0.004)	25.0(0.002)	25.0(0.002)	25.0(0.002)	25.0(0.002)	25.0(0.002)
Chrysene	34.1(0.001)	34.1(0.004)	34.1(0.004)	34.1(0.004)	34.1(0.004)	34.1(0.004)

* Expressed in micrograms per kilogram (standard error in parentheses).

** Value below method detection limit (present in trace amounts).

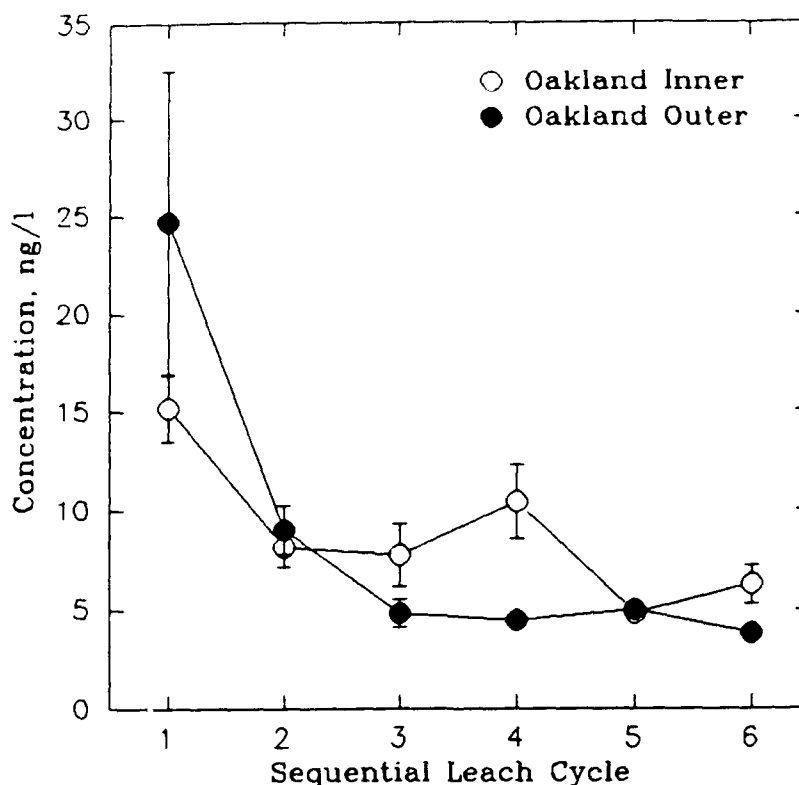


Figure V-10. Pyrene Concentration in Aerobic Oakland Harbor Sequential Batch Leachate

Percent loss of metals were generally higher in leachate from aerobic Oakland Inner and Outer Harbor sediment than from the respective anaerobic sediment (Table V-26). Percent loss of butyltin compounds were either similar to or lower in leachate from aerobic Oakland sediment than from anaerobic Oakland sediment.

Cumulative and percentage losses of PAHs during leaching. Cumulative net mass releases of PAH compounds from Oakland Inner and Outer Harbor sediments were generally similar between anaerobic sediments or aerobic sediments (Table V-27). Cumulative net mass PAH releases following leaching of aerobic sediment were much lower than releases from anaerobic sediment, reflecting the lower sediment concentrations of the PAH compounds following aerobic incubation. Releases of 0.00 $\mu\text{g}/\text{kg}$ reflects either the lack of detection of the compound in the leachate or the sediment.

Percent loss of PAH compounds from Oakland Inner and Outer Harbor sediments were generally similar between anaerobic sediments or aerobic sediments (Table V-28). Percent loss of PAH following leaching of aerobic sediment were much lower than releases from anaerobic sediment, reflecting the lower

Table V-25

Percent Mass Loss of Heavy Metals from Oakland Harbor Sediment
Under Anaerobic and Aerobic Conditions Following Seven
Sequential Batch Leach Cycles

<u>Parameter</u>	<u>(OH1)</u>		<u>(OH0)</u>	
	<u>Oakland Inner</u>		<u>Oakland Outer</u>	
	<u>Anaerobic</u>	<u>Aerobic</u>	<u>Anaerobic</u>	<u>Aerobic</u>
As	6.22	8.01	9.28	11.44
Zn	3.10	3.27	2.00	3.42
Cu	3.36	5.40	6.01	6.65
Ni	0.92	1.38	0.87	1.35
Cr	0.04	0.22	0.14	0.33
Ag	18.18	36.36	1.62	18.84
Pb	8.13	4.59	3.57	6.25
Cd	4.05	12.84	5.58	9.01
Hg	0.00	0.68	0.00	0.30
Tributyltin	5.25	0.00	8.93	24.07
Dibutyltin	7.573	7.31	8.800	0.00
Monobutyltin	45.0	0.00	7.56	0.00

Table V-26

Cumulative Mass Loss of PAH Compounds ($\mu\text{g/kg}$)
From Oakland Harbor Sediments Following 6 Cycles of Leaching

<u>Parameter</u>	<u>(OH1)</u>		<u>(OH0)</u>	
	<u>Oakland Inner</u>		<u>Oakland Outer</u>	
	<u>Anaerobic</u>	<u>Aerobic</u>	<u>Anaerobic</u>	<u>Aerobic</u>
Benzo(b,j,k)fluoranthene	2.17	0.00	1.90	0.00
Benzo(a)pyrene	1.30	0.00	0.60	0.00
Indeno(1,2,3-c,d)pyrene	0.40	0.00	0.20	0.00
Benzo(g,h,i)-perylene	0.53	0.00	0.40	0.00
Naphthalene	0.75	0.00	0.58	0.00
Phenanthrene	0.93	0.00	0.70	0.10
Fluoranthrene	1.40	0.10	1.50	0.10
Pyrene	4.63	0.48	3.30	0.20
Benzo(a)-anthracene	0.47	0.00	0.30	0.00
Chrysene	0.40	0.00	0.40	0.00
Acenaphthylene	0.06	0.00	0.00	0.00
Fluorene	0.04	0.00	0.00	0.00
Anthracene	0.04	0.00	0.00	0.00
Acenaphthene	0.06	0.00	0.00	0.00

Table V-27

Percent Mass Loss of PAHs from Oakland Harbor Sediment
Under Anaerobic and Aerobic Conditions Following Six
Sequential Batch Leach Cycles

Parameter	(OH1)		(OH0)	
	Oakland Inner		Oakland Outer	
	Anaerobic	Aerobic	Anaerobic	Aerobic
Benzo(b,j,k)fluoranthene	1.42	0.00	1.44	0.00
Benzo(a)pyrene	1.18	0.00	0.65	0.00
Indeno(1,2,3-c,d)pyrene	0.47	0.00	0.22	0.00
Benzo(g,h,i)-perylene	0.48	0.00	0.33	0.00
Naphthalene	9.38	0.00	7.25	0.00
Phenanthrene	3.83	0.00	2.97	0.49
Fluoranthrene	1.97	0.14	3.00	0.17
Pyrene	4.63	0.33	3.93	0.19
Benzo(a)-anthracene	0.47	0.00	0.75	0.00
Chrysene	0.40	0.00	0.80	0.00
Acenaphthylene	0.06	0.00	0.00	0.00
Fluorene	0.04	0.00	0.00	0.00
Anthracene	0.04	0.00	0.00	0.00
Acenaphthene	0.06	0.00	0.00	0.00

Table V-28

Cumulative Mass Loss (mg/kg) of Metals and Butyltin Compounds ($\mu\text{g/kg}$)
from Oakland Harbor Sediments Following 7 Cycles of
Leaching for Metals and 6 Cycles of Leaching
for Butyltin Compounds

Parameter	(OH1)		(OH0)	
	Oakland Inner		Oakland Outer	
	Anaerobic	Aerobic	Anaerobic	Aerobic
As	0.35	0.45	0.64	0.79
Zn	1.90	2.00	1.70	2.90
Cu	0.83	1.33	1.87	2.07
Ni	0.60	0.90	0.73	1.13
Cr	0.15	0.85	0.50	1.20
Ag	0.02	0.04	0.003	0.04
Pb	1.15	0.65	0.67	1.17
Cd	0.006	0.19	0.013	0.021
Hg	0.00	0.01	0.000	0.0005
Tributyltin	0.27	0.00	0.256	0.65
Dibutyltin	0.34	0.30	0.220	0.000
Monobutyltin	0.09	0.00	0.063	0.000

sediment concentrations of the PAH compounds and corresponding lower releases following aerobic incubation.

Column Leaching Results

Column operating parameters. Column operating parameters are shown in Table V-29. The data in Table V-29 show that there were no differences in column operating parameters for metals and organics. As previously discussed, the use of separate columns for metals and organics is primarily one of convenience for collection and preservation of samples.

Column length is fixed by the column geometry and is therefore the same for all columns. Porosity, specific gravity, and water content are sediment dependent, but are the same for a given sediment. These parameters were determined on one sample collected during loading of the columns. Average pore water velocity and the dispersion coefficient are about the same for all the columns. Average pore water velocity values were obtained from column operating records and dispersion coefficients were obtained by fitting the advection-dispersion equation (Hill, Myers, and Brannon 1988) to observed elution curves for electrical conductivity. Dispersion coefficients are discussed in more detail in a later section.

Data presentation format. Column leachate data are reported as a function of the number of pore volumes eluted from the columns. One pore volume is that volume in the sediment occupied by water. Since the columns were operated in a saturated condition, all the voids were filled by water. Figure V-11 illustrates the pore volume concept.

For saturated conditions, the pore volume is given by

$$P_v = A L n \quad (1)$$

where

P_v = pore volume of the sediment, cm^3

A = cross-sectional surface area of the sediment column, cm^2

L = length of the sediment column, cm

n = porosity, dimensionless

Table V-29
Column^a Operating Parameters

<u>Sediment</u>	<u>Col.</u>	<u>Type</u>	<u>n</u>	<u>SG</u>	<u>W</u>	<u>V</u>	<u>D_p</u>
Oakland	10	metal	.47	2.73	0.323	1.5E-05	6.0E-07
Inner	11	metal	.47	2.73	0.323	1.2E-05	4.8E-07
(OH11)	12	metal	.47	2.73	0.323	1.4E-05	5.6E-07
	17	organic	.47	2.73	0.323	1.8E-05	ND
	18	organic	.47	2.73	0.323	2.8E-05	ND
Oakland	1	metal	.77	2.76	1.187	5.8E-06	1.3E-07
Outer	2	metal	.77	2.76	1.187	5.0E-06	1.1E-07
(OHO)	3	metal	.77	2.76	1.187	5.1E-06	1.1E-07
	7	organic	.77	2.76	1.187	9.5E-06	ND
	8	organic	.77	2.76	1.187	1.2E-05	ND

a: length equal 4 cm
 ND: no data
 n: porosity
 SG: specific gravity
 w: water content, weight of water/weight of solids
 V: average pore water velocity, cm/sec
 D_p: dispersion coefficient, cm²/sec

The number of pore volumes eluted is the cumulative volume of water collected divided by P_v. For the steady flow conditions maintained during column leaching, the number of pore volumes eluted is also given by

$$T = \frac{Q t}{P_v} = \frac{A V_d n t}{A L n} = \frac{V t}{L n} \quad (2)$$

where

Q - flow, cm³/sec

T - pore volumes eluted

t - time, sec

V_d - Darcy velocity, cm/sec

The field time for elution of one pore volume is given by

$$T' = \frac{1}{T} = \frac{L n}{V_d} \quad (3)$$

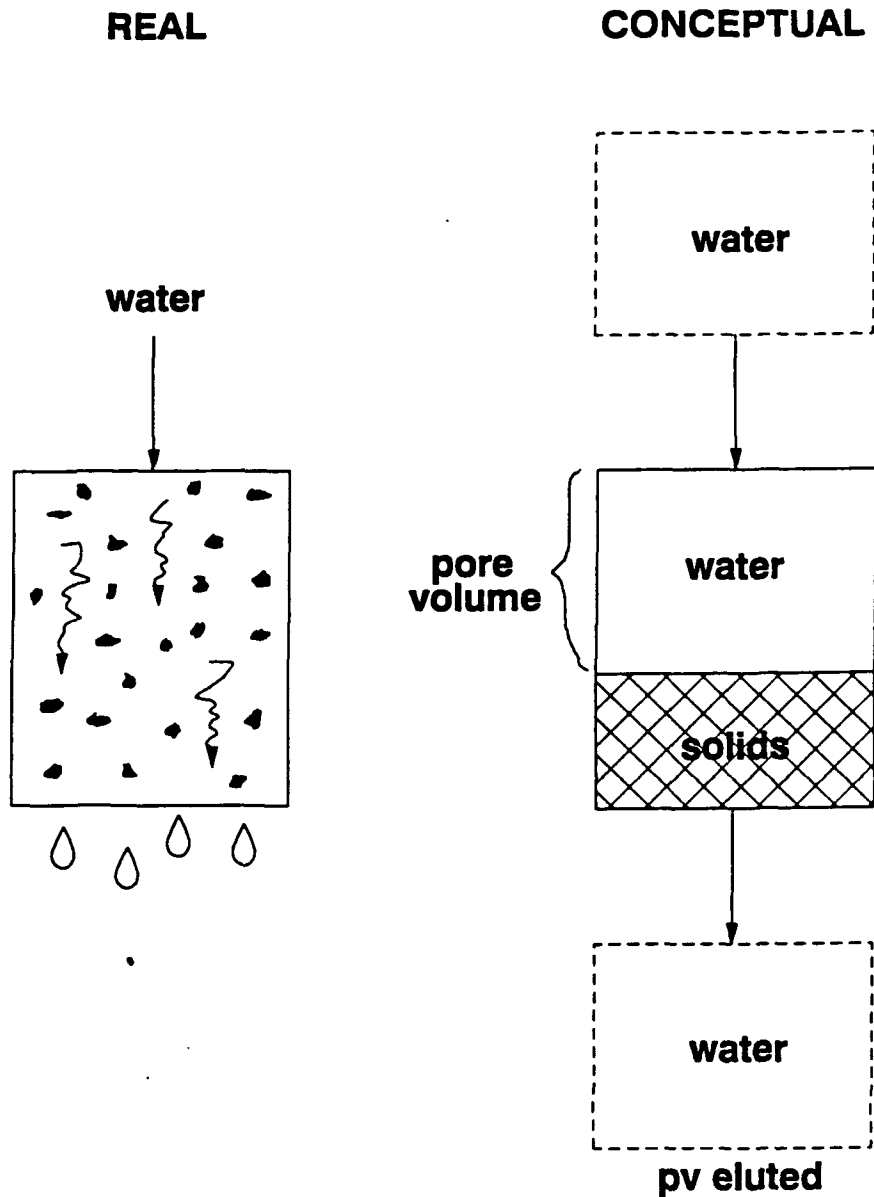


Figure V-11. Pore Volume Definition Sketch

where T' is the time to elute one pore volume. For saturated dredged material with no standing water, the Darcy velocity is equal to the hydraulic conductivity of the dredged material. For saturated dredged material in an upland disposal facility of area A , the field elution time for one pore volume of water is given by

$$T' = \frac{A L n}{A K} = \frac{L n}{K} \quad (4)$$

where

L = depth of dredged material fill, cm

K = hydraulic conductivity, cm/sec

For example, if L = 457 cm (15 ft), K = 1 E-06 cm/sec, and n = 0.6, then the field elution time for one pore volume is about nine years.

The discussion above illustrates how to convert laboratory time for column leaching studies to an equivalent field time. Because the sediment pore volume is the basis for relating laboratory column time to field time, it is, therefore, convenient to present column elution curves as contaminant concentration versus pore volumes eluted.

General column leachate quality. Figures V-12 and V-13 show pH and electrical conductivity in column leachates. During column leaching of Oakland Inner Harbor sediment, pH in leachate from columns operated for testing of metals (Figure V-12) and organics (Figure V-13) was about the same. The pH of column leachate from Oakland Outer Harbor sediment was slightly higher than the pH of column leachate from Oakland Inner Harbor sediment. The difference was probably too small to affect metal leaching. The pH of column leachate from Oakland Inner Harbor sediment was about the same as the pH of anaerobic batch leachate from Oakland Inner Harbor sediment (Table V-8). In both cases, pH was generally steady throughout the leaching procedure. The pH of column leachate from Oakland Outer Harbor sediment was about the same as the pH of anaerobic batch leachate from Oakland Outer Harbor sediment (Table V-8). In the column leach test, however, pH tended to increase slightly from initial values and then remain steady in 4 of the 5 columns. In one column (column 2), there was a drop in pH after two pore volumes were eluted (Figure V-12). By the time three pore volumes had been eluted, the pH in column 2 was back in line with the pH in the other columns. In the anaerobic sequential batch leach test on Oakland Outer Harbor sediment, pH showed no distinct trends (Table V-8).

The electrical conductivity of column leachates showed classical washout curves as expected for all but one column. Since electrical conductivity is a measure of dissolved salts and the estuarine sediments from Oakland Inner and Outer Harbor were leached with distilled-deionized water, a washout curve is

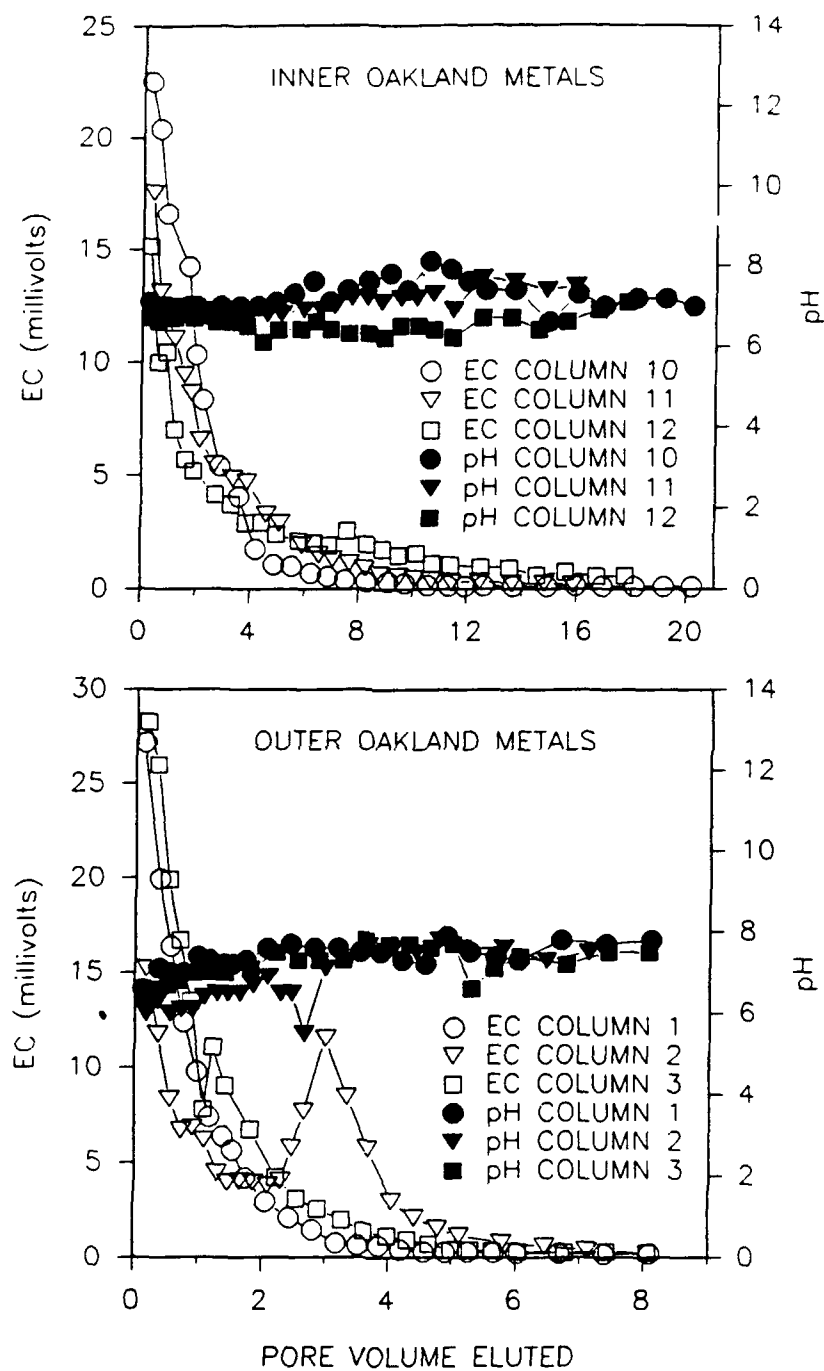


Figure V-12. Electrical Conductivity and pH in Column Leachates Collected for Metals Analysis

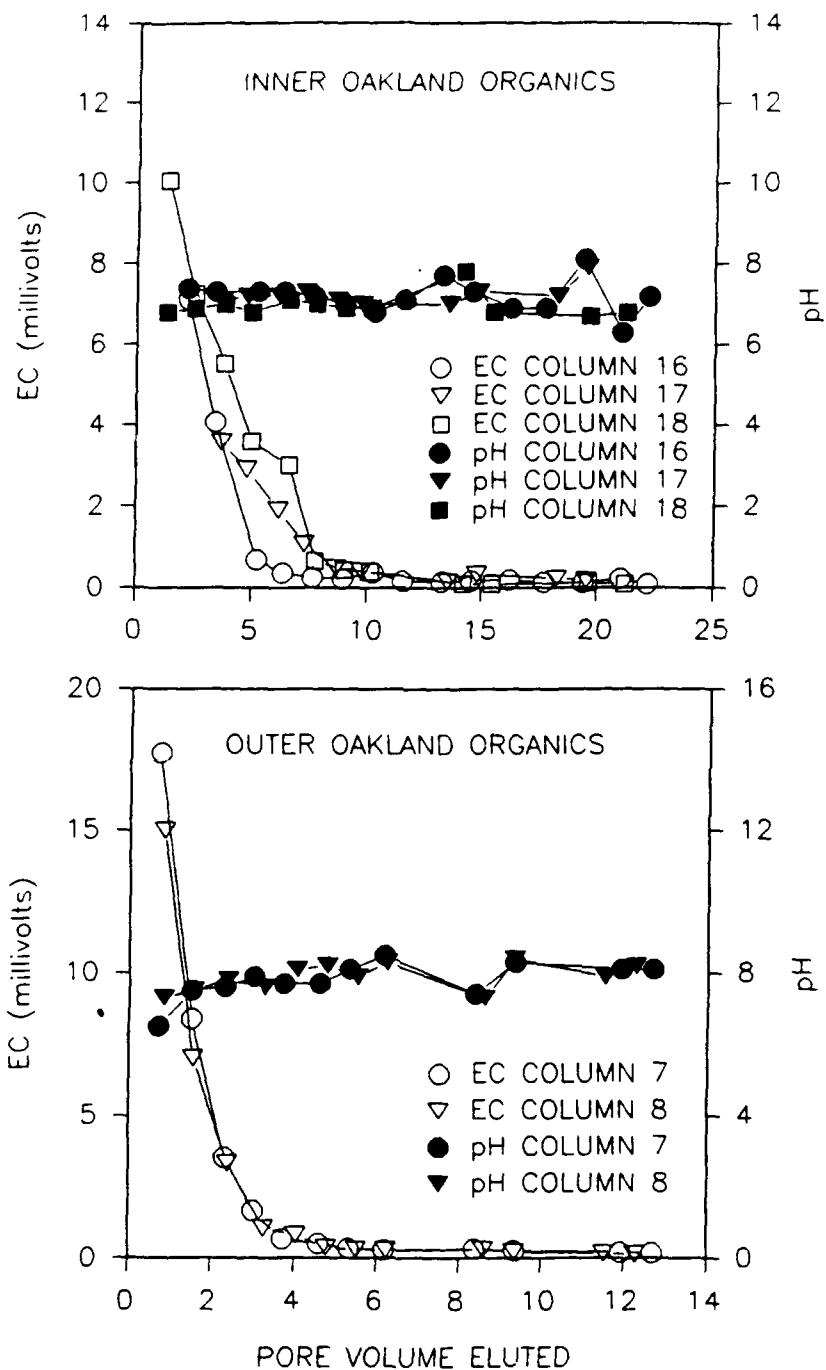


Figure V-13. Electrical Conductivity and pH in Column Leachates Collected for Butyltin and PAH Analyses

expected. The electrical conductivity versus pore volumes eluted plot should monotonically decrease, that is, electrical conductivity should never increase. Column 2 (Figure V-12) showed an unanticipated rise in electrical conductivity between 2 and 4 pore volumes eluted. The increase in electrical conductivity in column 2 is apparently associated with the drop in pH in column 2 previously discussed. The electrical conductivity data on column 2 suggests that an isolated pocket in the sediment through which water had not been flowing opened up and began to transmit water.

The dispersion coefficients in Table V-29 were estimated by fitting the advection-dispersion equation to electrical conductivity data for each sediment. The one-dimensional solution of Ogata and Banks (1961) for the advection-dispersion equation as programmed for application on a desktop computer by Beljin (1985) was fitted in a trial and error fashion. Typical results for observed and fitted electrical conductivity elution curves are shown in Figure V-14. Also shown in Figure 14 are electrical conductivity elution curves predicted by a complete mix model equation. Although the complete mix model neglects spatial variation in leachate quality, the complete mix model was in good agreement with observed electrical conductivity elution curves for Oakland Outer Harbor sediment. Agreement between the complete mix model and observed electrical conductivity elution curves for Oakland Inner Harbor sediment was not as good as with Oakland Outer Harbor sediment. The lack of agreement indicates that spatial variability in leachate quality due to convective and dispersive processes is greater in Oakland Inner Harbor sediment than in Oakland Outer Harbor sediment. These differences are probably related to differences in porosity and water content.

Metals in Oakland Inner Harbor column leachates. Metals elution curves for Oakland Inner Harbor sediment are shown in Figures V-15 through V-17. Complete data sets are provided in Appendix D. Metals concentrations, except for chromium, were generally very low in column leachates from Oakland Inner Harbor sediment.

There were no distinct trends in silver elution from Oakland Inner Harbor sediment. The highest concentration ($3.65 \mu\text{g/L}$) was measured in the initial sample from column 12. Except for this one value that was not replicated in the other columns, silver concentrations were less than $1 \mu\text{g/L}$ throughout most of the test. The type of elution curves suggest that the amount of leachable silver in Oakland Inner Harbor sediment is very small and leachate concentrations will tend to be less than $1 \mu\text{g/L}$.

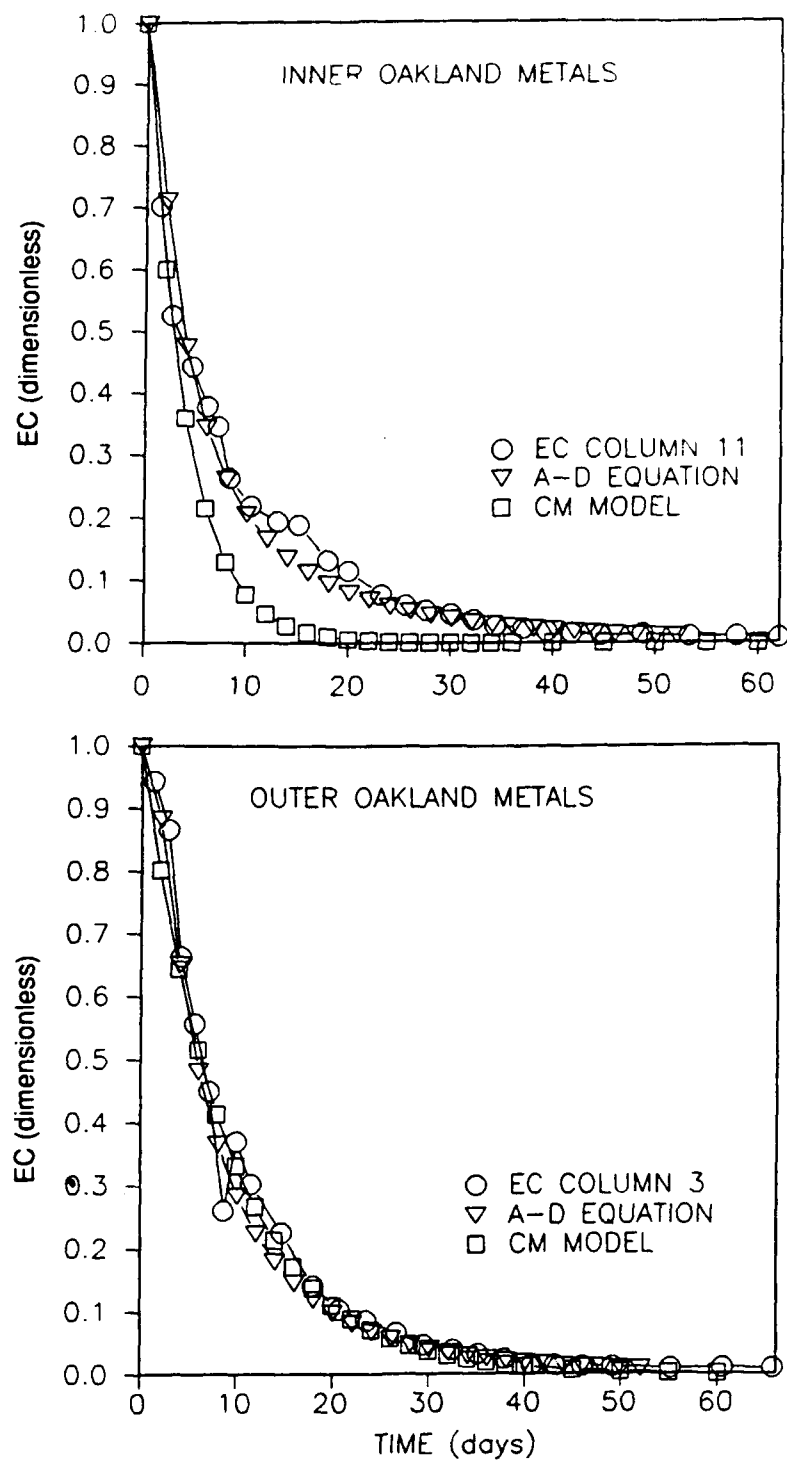


Figure V-14. Fitted and Observed Electrical Conductivity Elution Curves (normalized for maximum observed value)

Arsenic which ranged from less than 1 to 33 eeg/L showed highest values early in the test (2 to 4 pore volumes eluted) and thereafter tended to fluctuate in the range of 5 to 15 eeg/L. This type of elution curve suggests that a reservoir of leachable arsenic resides in the sediment solids that can maintain concentrations at the levels indicated for a long period of time.

Cadmium concentrations dropped from initial values around 1 eeg/L to concentrations that were consistently less than 0.5 eeg/L for two of the three columns. In column 10 (Figure V-15), the maximum value, an apparent outlier, occurred at 14 pore volumes eluted. The type of elution curve shown in columns 11 and 12 for cadmium suggests that initial cadmium concentrations in dredged material pore water will be reduced by convective transport and a reservoir of leachable cadmium resides in the sediment solids that can maintain concentrations at the reduced levels indicated for a long period of time.

Chromium showed a complicated elution history. Chromium concentrations tended to increase very slowly up to 4 pore volumes eluted in all three columns. In column 10, concentrations then decreased and never returned to the original levels. In column 11, chromium concentrations remained at or slightly higher than the initial values until 6 pore volumes were eluted. Thereafter, the chromium concentrations in column 11 decreased and, as with column 10, never returned to the original levels. In column 12, chromium concentrations were somewhat erratic after 6 pore volumes were eluted, but after 12 pore volumes were eluted begin to show the type of decrease observed in columns 10 and 11. The elution curves for columns 10 and 11 suggests that as leaching proceeds the geochemical form(s) of chromium is altered so that sediment bound chromium becomes slightly more leachable and then less leachable. The elution curve for column 12 is similar except that the leachable reservoir is more persistent and the decrease in chromium concentrations is subsequently delayed.

Copper concentrations increased in two of the three columns. In one column (column 12, Figure V-16), very low copper concentrations were eluted after the first sample was collected. In the other two columns, copper showed a trend for increasing concentrations between 4 and 12 pore volumes eluted and, thereafter, copper concentrations tended to stabilize. Lead elution curves for Oakland Inner Harbor sediment (Figure V-16) were similar to the copper elution curves, except that the increase in lead concentrations eluted

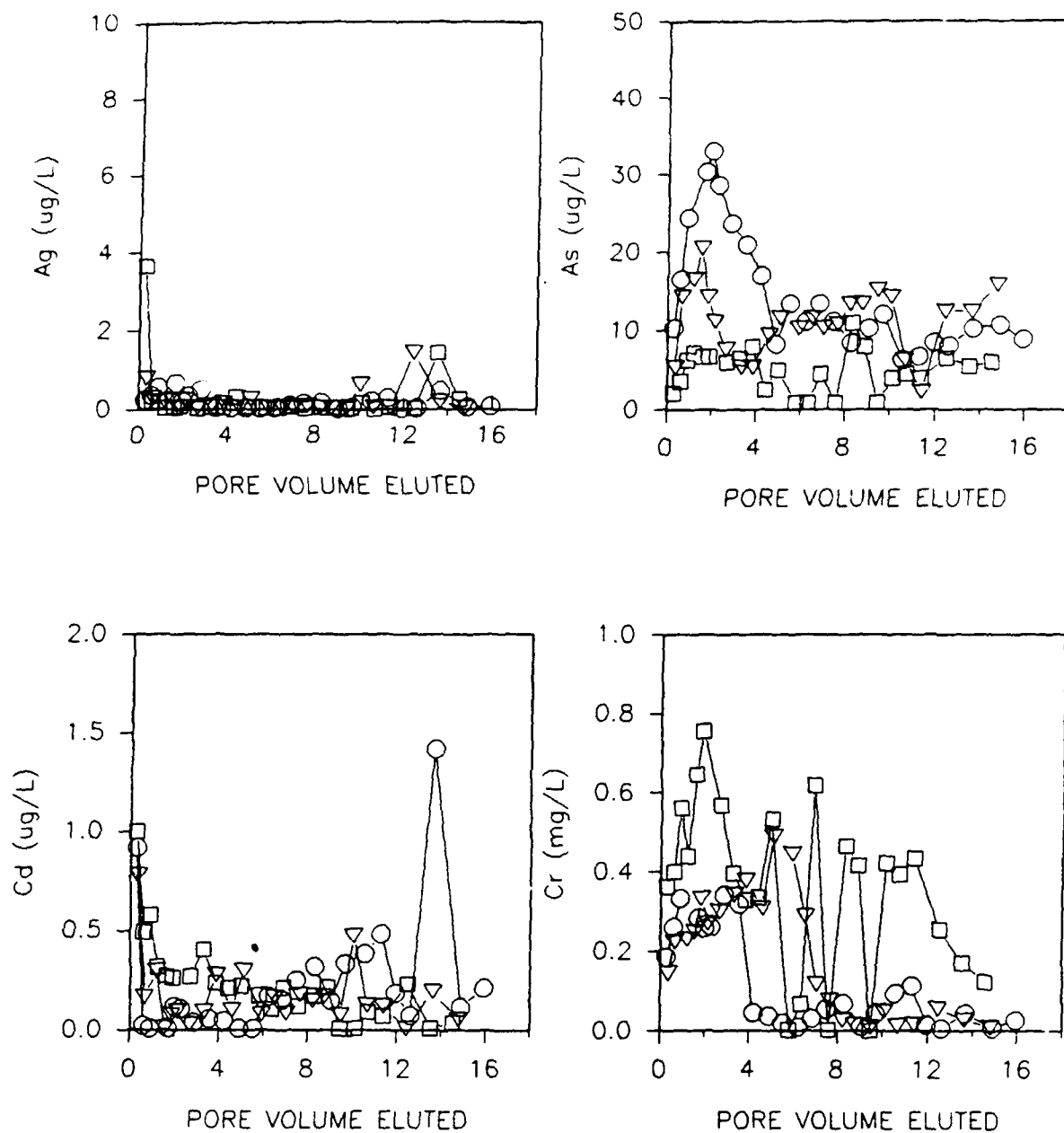


Figure V-15. Silver, Arsenic, Cadmium, and Chromium Elution Curves for Oakland Inner Harbor Sediment (circles - col. 10, triangles - col. 11, squares - col. 12)

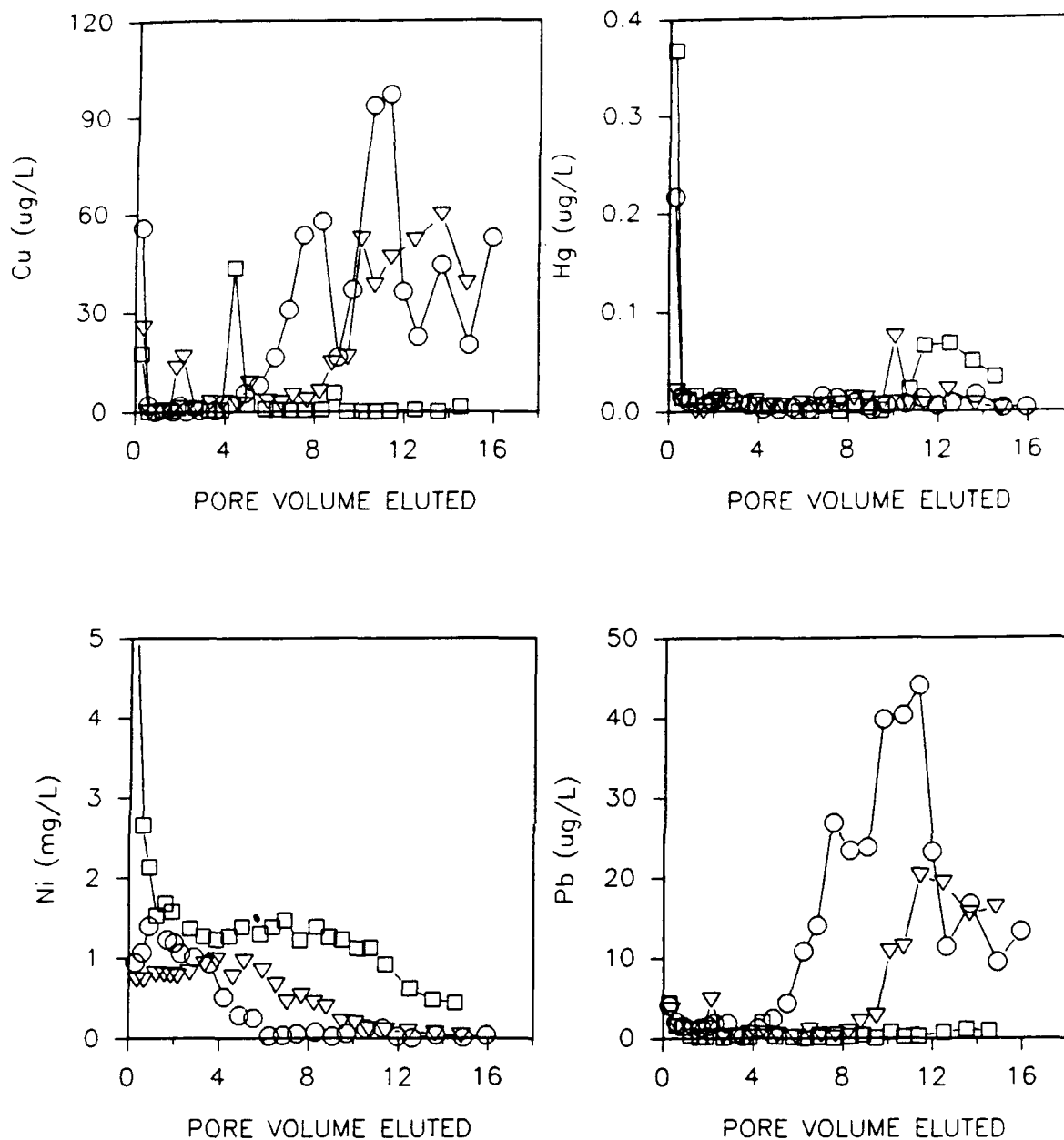


Figure V-16. Copper, mercury, nickel, and lead elution curves for Oakland Inner Harbor sediment (circle - col. 10, triangles - col. 11, squares - col. 12)

from columns 10 and 11 was more distinct than the increases in copper concentrations for these columns. The type of elution curves observed for copper and lead in columns 10 and 11 suggests that leachable reservoirs of copper and lead are initially low, then increase, and finally begin to decline.

The mercury elution curves (Figure V-16) showed a rapid decrease from initial values in two of the columns to concentrations that were near or below $0.01 \mu\text{g/L}$ for most of the samples collected after the initial sample. There was a slight increase after 12 pore volumes were eluted. One column (column 11, Figure V-16) eluted very low mercury concentrations throughout the column leaching test. Thus, mercury elution was similar to that of silver (Figure V-15). The mercury elution curves suggest very low levels of leachable mercury.

Nickel concentrations, with the exception of column 12, tended to be stable for several pore volumes, then decrease. This type of elution curve suggests that there is a reservoir of leachable nickel that is slowly depleted. The first sample collected from one column, column 12, was very high relative to the nickel concentrations in leachates from the other two columns. Apparently the pore water in this column contained a high level of nickel that was removed by convection of water. After 2 pore volumes were eluted the nickel concentrations in leachate from this column were in line with the nickel concentrations from the other two columns up to about 6 pore volumes. Thereafter the nickel concentrations in column 12 were higher than in leachates from columns 10 and 11 but the overall trends were the same.

Zinc concentrations (Figure V-17) decreased from initial values up to about 8 pore volumes eluted. The high value in column 10 at about 2 pore volumes is probably an outlier that should not be given much significance. After 8 pore volumes, zinc concentrations tended to stabilize or slightly increase. The elution curves shown in Figure V-17 suggest that initial zinc concentrations in dredged material pore water are reduced by convective transport and a reservoir of leachable zinc resides in the sediment solids that can maintain concentrations at the reduced levels indicated for a long period of time.

Metals in Oakland Outer Harbor column leachates. Metals elution curves for Oakland Outer Harbor sediment are shown in Figures V-18 through V-20. Complete data sets are provided in Appendix D. Metals concentrations, except for chromium, were generally very low in column leachates from Oakland Outer Harbor sediment. Initial concentrations from one column, column 2, were

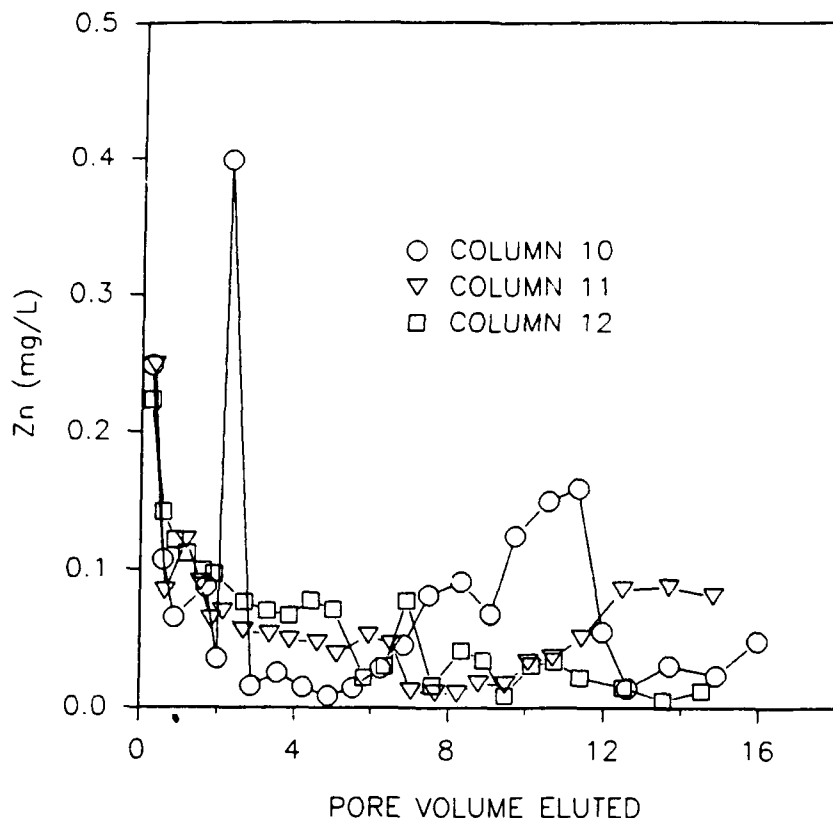


Figure V-17. Zinc Elution Curves for Oakland Inner Harbor Sediment

significantly higher in chromium, copper, lead, and zinc. Long-term trends and concentrations in this column were similar to the other two columns.

Silver concentrations were somewhat erratic initially (Figure V-18) and then after elution of 2 pore volumes tended to stabilize between about 0.01 and 0.1 $\mu\text{g/L}$. This type of elution curve suggests that the sediment pore water is the initial reservoir of leachable silver. Following elution of pore water silver, sediment bound silver desorbs to a small extent.

Arsenic showed a complicated elution curve (Figure V-18) in which initial concentrations dropped to a relative minimum after elution of approximately 1 pore volume, increased to a relative maximum between 3 and 4 pore volumes eluted, and then tended to decrease. Initial concentrations ranged from 58 to 70 $\mu\text{g/L}$ and the relative maximum concentrations between 3 and 4 pore volumes eluted ranged from 40 to 85 $\mu\text{g/L}$. Cadmium elution curves were similar to arsenic elution curves except that the relative maximum at 3 pore volumes eluted in column 2 was followed by a third relative maximum. The

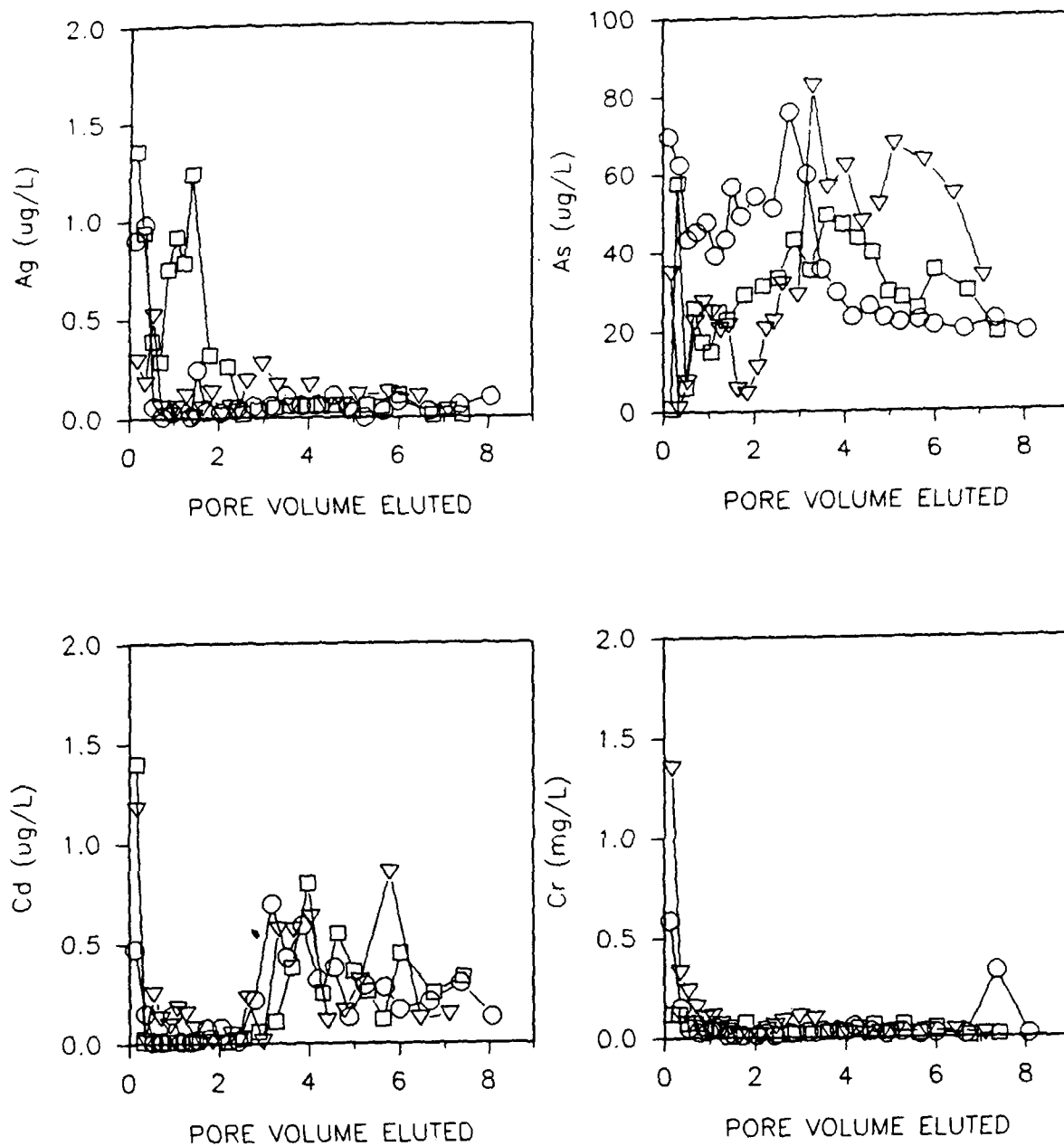


Figure V-18. Silver, Arsenic, Cadmium, and Chromium Elution Curves for Oakland Outer Harbor Sediment (circles - col. 1, triangles - column 2, squares - col. 3)

elution curves for arsenic and cadmium suggest that initial leachate contaminant concentrations may not be the maximum leachate contaminant concentrations and maximum contaminant concentrations may not be observed until after several pore volumes have been eluted.

Chromium elution curves (Figure V-18) rapidly decrease from initial values to concentrations that were generally less than 100 $\mu\text{g/L}$. The chromium elution curves suggest initially high levels of pore water chromium that is diluted by water convection. Dilution is partially offset by desorption from the sediment solids so that long-term chromium concentrations are in the range of 100 $\mu\text{g/L}$ or less.

Copper and lead showed the same elution trend (Figure V-20) as arsenic (Figure V-18) except the trend for increasing concentrations after the drop in initial concentrations was better defined and delayed relative to the arsenic curve. The type of elution curves observed for copper and lead in Outer Oakland sediment suggests that leachable reservoirs of copper and lead are initially low and then increase.

The mercury elution curves for Oakland Outer Harbor sediment (Figure V-19) showed a slow decrease from initial values around 0.06 $\mu\text{g/L}$ to concentrations around 0.003 $\mu\text{g/L}$ or less. The mercury elution curve has the shape of a classical desorption curve, indicating that initial mercury concentrations are replenished by a reservoir of leachable mercury in the sediment solids that can maintain concentrations at reduced levels for a very long time.

Nickel and zinc elution curves for Oakland Outer Harbor sediment (Figures V-19 and V-20, respectively) showed a rapid decrease from initial values to concentrations that tended to remain steady for most of the samples collected after the first pore volume was eluted. These elution curves suggest that the sediment pore water is the initial reservoir of leachable nickel and zinc and that after the nickel and zinc in the pore water is eluted, sediment bound nickel and zinc desorbs only slightly.

Butyltin in Column Leachates. Butyltin concentrations in column leachates from Oakland Inner and Outer harbor sediments are provided in Table V-30. Tetrabutyltin was below the detection limits in all samples, and tributyltin was below the detection limit in most of the samples. These data indicate no release of tetrabutyltin and very low release of tributyltin during column leaching. Di- and monobutyltin releases were observed during column leaching, but there were no distinct trends in the data. Dibutyltin was the most abundant butyltin in column leachates. For Oakland Inner Harbor sediment, the

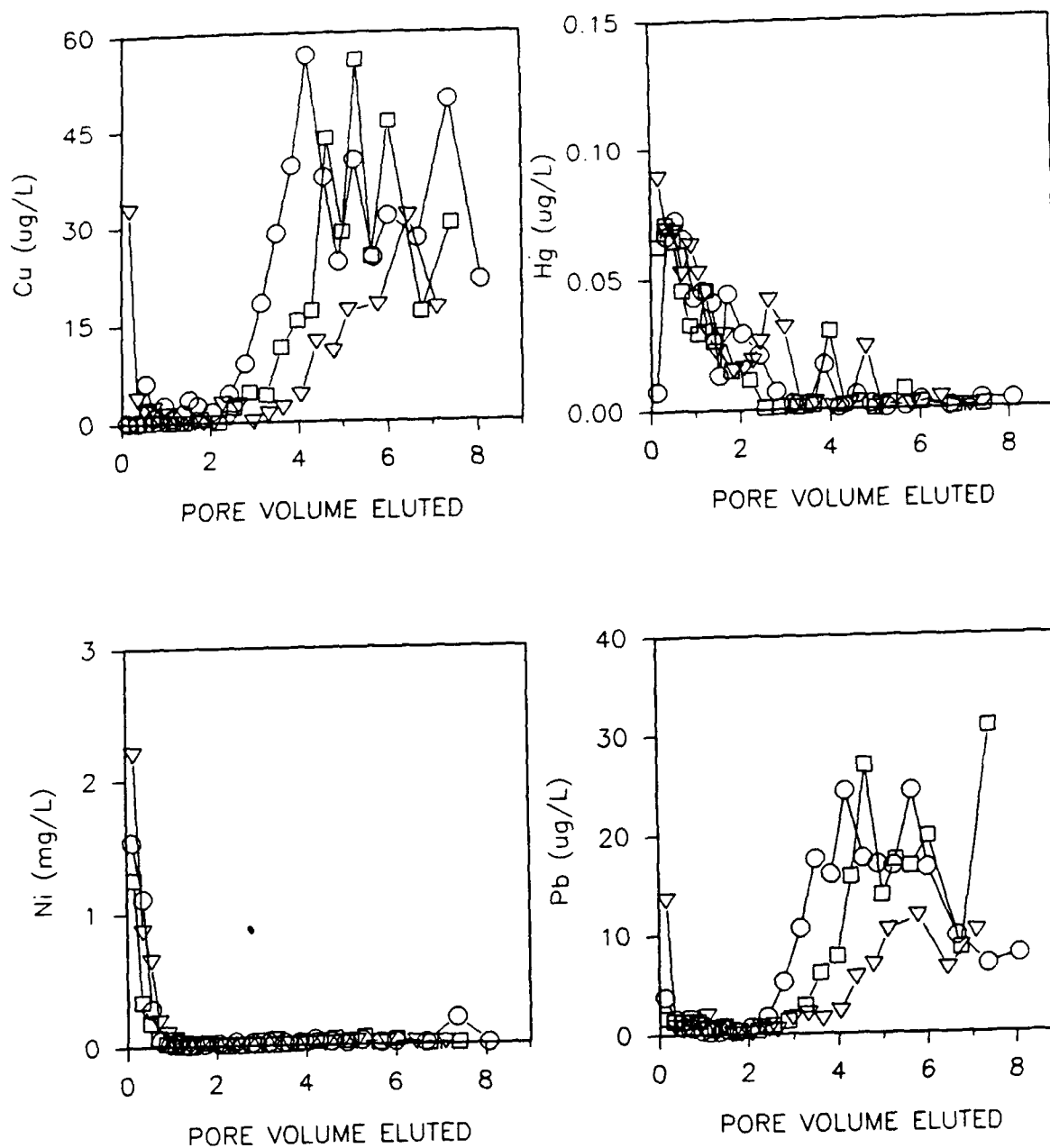


Figure V-19. Copper, Mercury, Nickel, and Lead Elution Curves for Oakland Outer Harbor Sediment (circles - col. 1, triangles - col. 2, squares - col. 3)

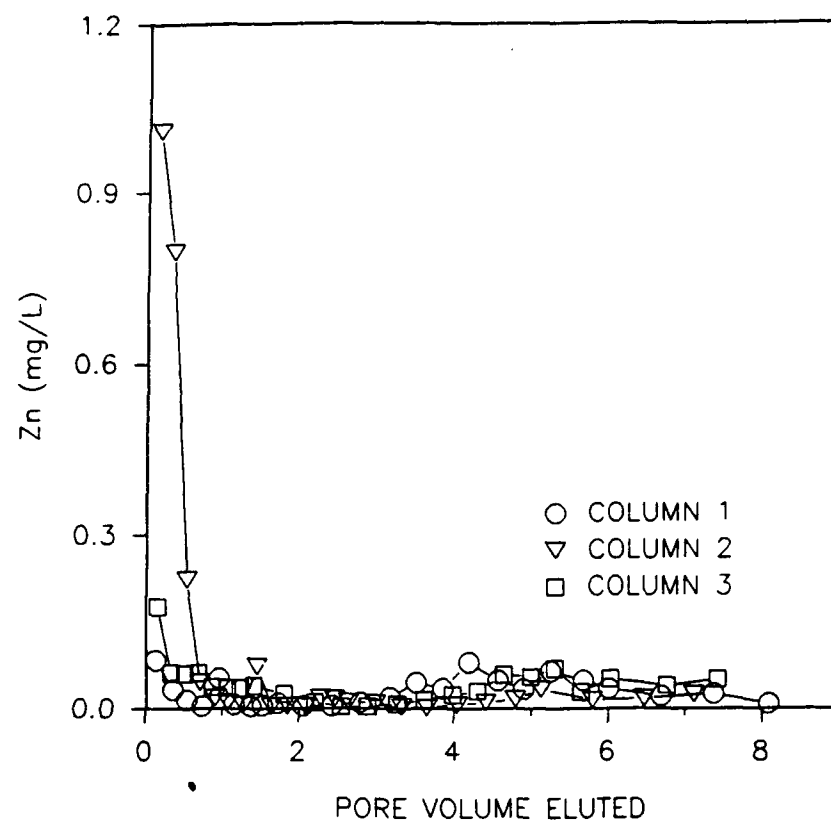


Figure V-20. Zinc Elution Curves for Oakland Outer Harbor Sediment

Table V-30
Butyltins in Column Leachates (ng/L)

	PV Eluted				
Oakland Inner (OH11)	<36.4	152.6	<22.5	<22.9	13.7
Column 17	2.5	4.8	7.3	9.8	19.6
4TBT	<9.6	<8.4	<9.3	<9.5	<8.1
3TBT	<36.4	<20.3	<22.5	<22.9	4.0
2TBT	38.9	152.6	20.7	7.5	41.5
1TBT	15.7	23.3	21.1	4.5	13.7
Column 18	2.5	4.5	7.8	10.2	21.2
4TBT	<7.6	<8.9	<8.1	<6.9	<9.7
3TBT	<18.4	<1.4	<1.5	<16.6	<0.9
2TBT	11.8	8.1	7.2	29.9	2.3
1TBT	9.6	1.8	5.9	16.5	<0.8
Column 7	1.5	2.3	4.6	6.2	12.7
4TBT	<8.6	<7.6	10.3	< 9.2	< 1.0
3TBT	1.1	4.4	2.9	---	10.7
2TBT	68.9	17.9	13.5	9.4	17.4
1TBT	12.1	4.8	5.7	1.5	13.9
Column 8	1.6	3.3	4.8	6.2	12.3
4TBT	< 8.6	< 7.7	< 8.6	< 8.4	< 0.9
3TBT	<20.7	<18.5	3.6	< 2.2	12.0
2TBT	46.0	15.8	82.6	34.7	20.4
1TBT	21.3	8.2	27.8	32.9	7.1

4TBT: Tetra-butyltin
3TBT: Tri-butyltin
2TBT: Di-butyltin
1TBT: Mono-butyltin

range in dibutyltin concentrations was 2.3 to 153 ng/L, the median value was 16.3 ng/L, and the mean value was 32.5 ng/L. For Oakland Outer Harbor sediment, the range in dibutyltin concentrations was 9.4 to 82.6 ng/L, the median value was 19.2 ng/L, and the mean value was 32.7 ng/L. Dibutyltin releases from Oakland Inner and Outer Harbor sediment during column leaching were, therefore, similar and averaged around 32 ng/L. For Oakland Inner Harbor sediment, the range in monobutyltin concentrations was less than 0.8 to 23.3 ng/L, the median value was 11.7 ng/L, and the mean value was 11.2 ng/L. For Oakland Outer Harbor sediment, the range in monobutyltin concentrations was 1.5 to 32.9 ng/L, the median value was 10.2 ng/L, and the mean value was 13.5 ng/L. Monobutyltin releases from Oakland Inner and Outer Harbor sediment during column leaching were, therefore, similar and averaged around 10 to 11 ng/L.

PAHs in column leachates. PAH compounds in column leachates were near or below the detection limit in most cases. The complete data set is presented in Appendix D. Fluoranthene and pyrene were exceptions. Figures V-21 and V-22 show fluoranthene and pyrene column elution curves for Oakland Inner and Outer Harbor sediments, respectively. Initial fluoranthene and pyrene concentrations were below the detection limits, but as column leaching proceeded concentrations of these two PAHs increased. With the exception of fluoranthene elution in column 18, fluoranthene and pyrene show a trend for increase after 2 pore volumes are eluted (Figures V-21 and V-22) that is similar to several of the metal elution curves. These elution curves suggest that leachable reservoirs of fluoranthene and pyrene in Oakland Harbor sediments are initially low and then increase.

Discussion

Sequential Batch Leach Data

Sequential batch leaching of both anaerobic and aerobic Oakland Harbor sediment did not follow classical desorption theory. The appearance of peaks in the leachate concentration data indicated nonconstant sediment geochemistry and nonconstant distribution coefficients during leaching. If constant distribution coefficients existed, contaminant concentrations would have decreased during sequential batch leaching. The changes in sediment geochemistry are reflected in the changes in conductivity during sequential leaching.

The nonconstant partitioning evident in the sequential batch leach data for Oakland Harbor sediments has been observed in previous leaching studies on estuarine sediments (Myers and Brannon 1988; Palermo et al. 1989). Nonconstant partitioning means that distribution coefficients change as the solid phase concentration decreases during sequential leaching until a turning point is reached (Figure V-23). The nonconstant portion of the desorption isotherm shown in Figure V-23 is related to elution of salt. As salt is eluted, the ionic strength of the aqueous phase is reduced. Decreasing ionic strength increases repulsive forces between colloids so that flocculated colloidal matter becomes dispersed in the water phase. Sediment colloids that become dispersed in the water phase carry can carry contaminants and increase the apparent dissolved concentration of these contaminants (Brannon et al. 1991).

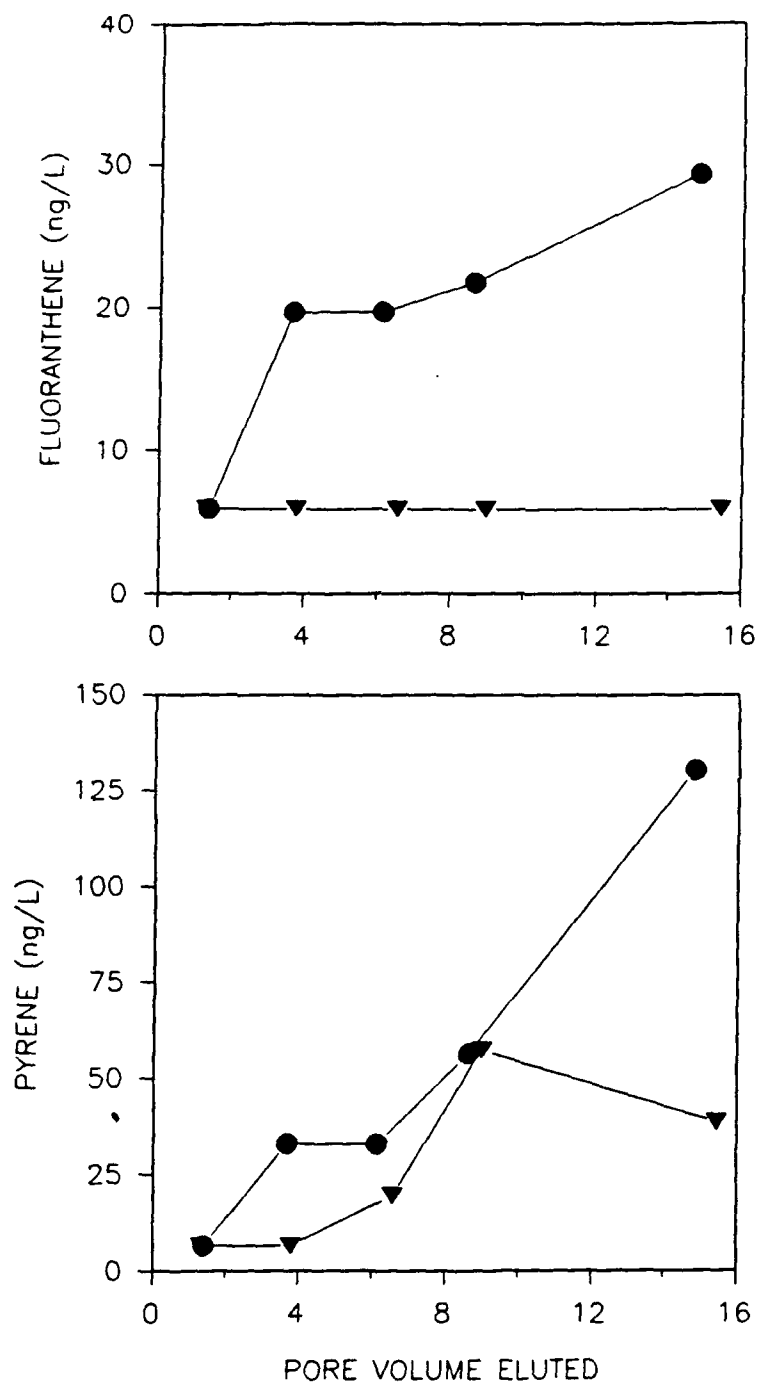


Figure V-21. Fluoranthene and Pyrene Elution Curves for Oakland Inner Harbor Sediment (circles - col. 17, triangles - col. 18)

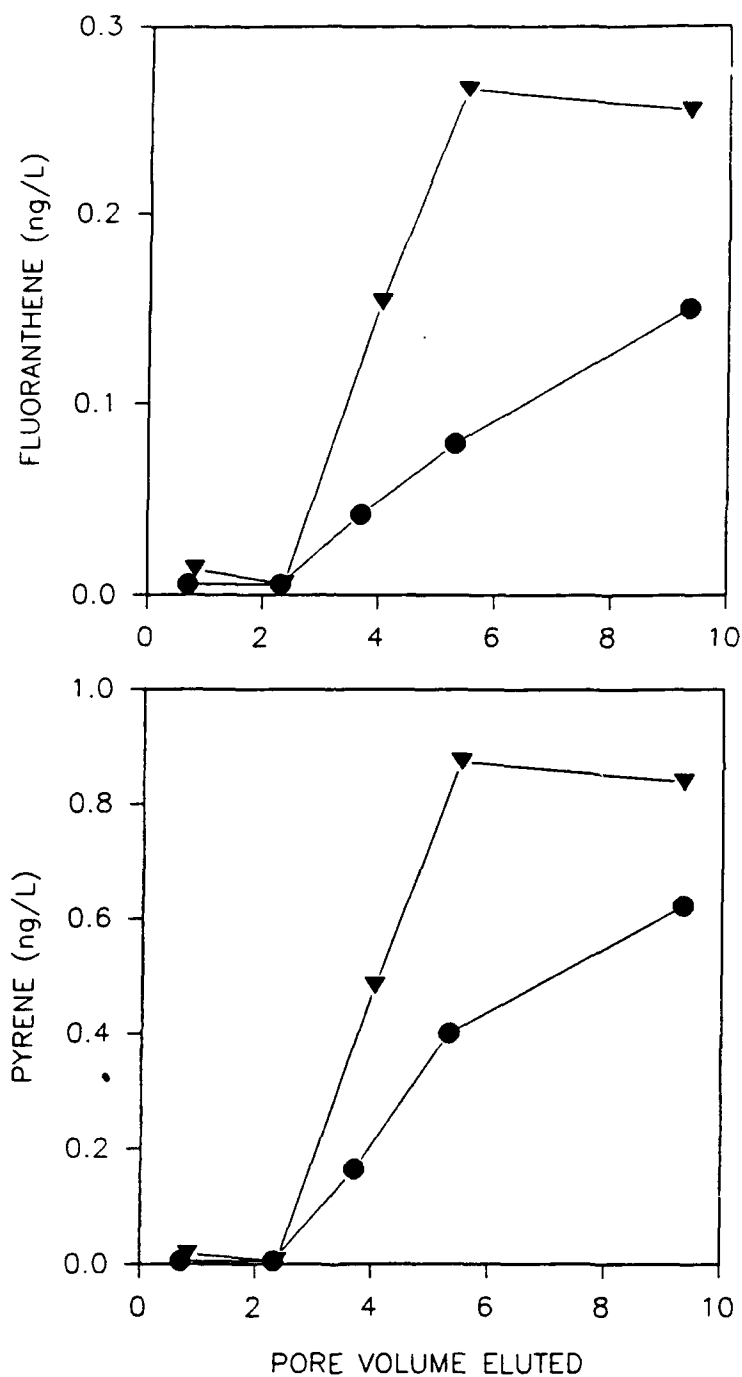


Figure V-22. Fluoranthene and Pyrene Elution Curves for Oakland Outer Harbor Sediment (circles - col. 17, triangles - col. 18)

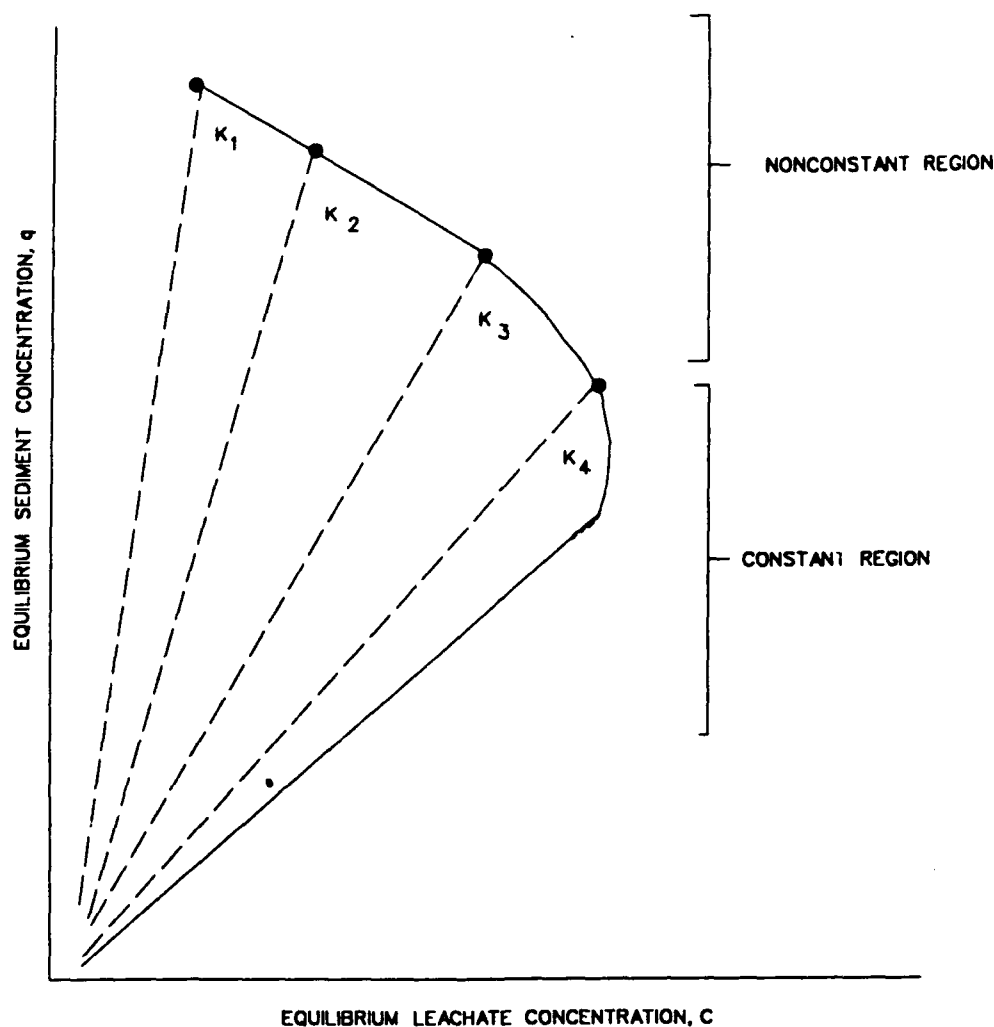


Figure V-23. Desorption Isotherm Illustrating Nonconstant and Constant Partitioning

Thus, deflocculation of sediment colloids is probably the process responsible for nonconstant partitioning.

Anaerobic isotherms. Figures V-24 through V-26 show desorption isotherm plots for copper, dibutyltin, and lead for anaerobic Oakland Inner and Outer Harbor sediments. The points in these figures are sediment contaminant concentration-leachate contaminant concentration pairs from the sequential batch leach data. Thus, the seven points in each figure represent the seven cycles in the sequential batch leach test. The highest point relative to the vertical axis is the data pair from the first cycle, the second highest point

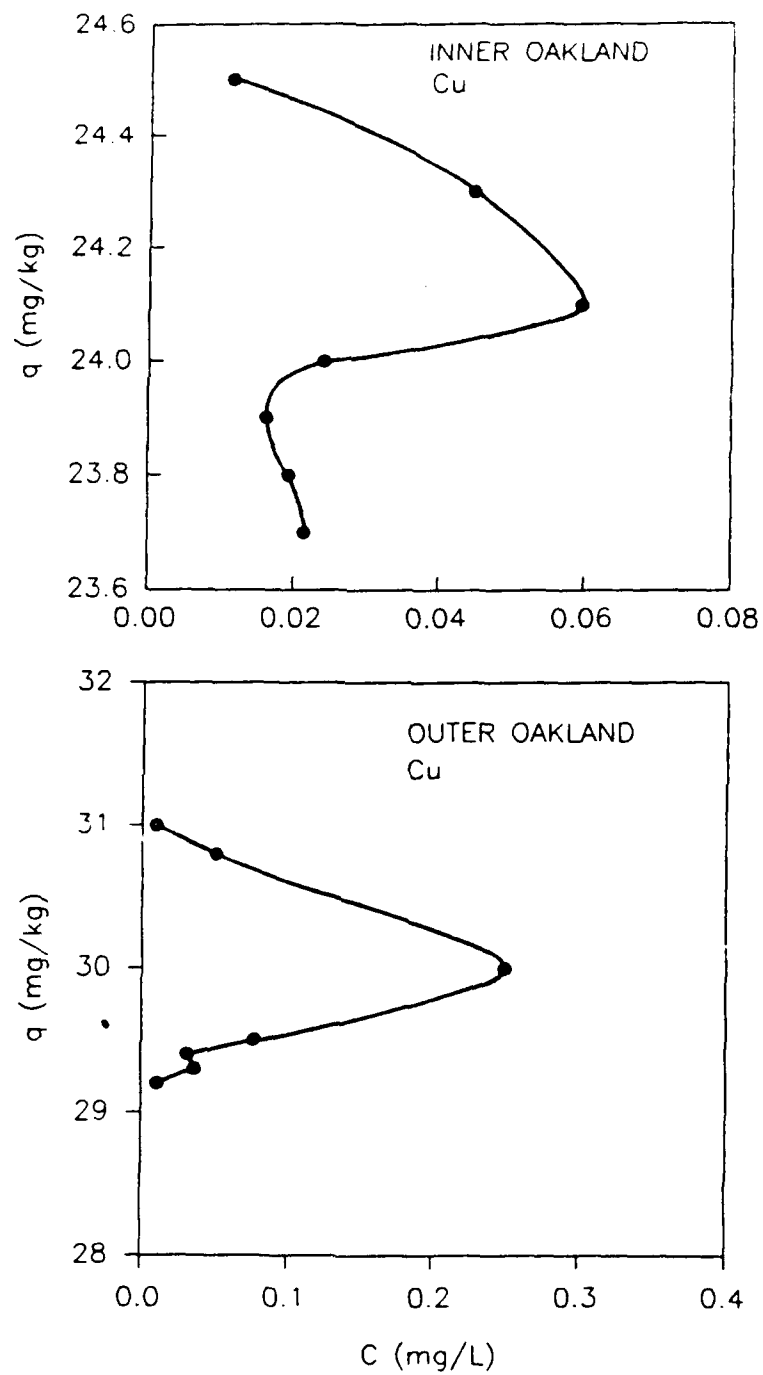


Figure V-24. Desorption Isotherms for Copper

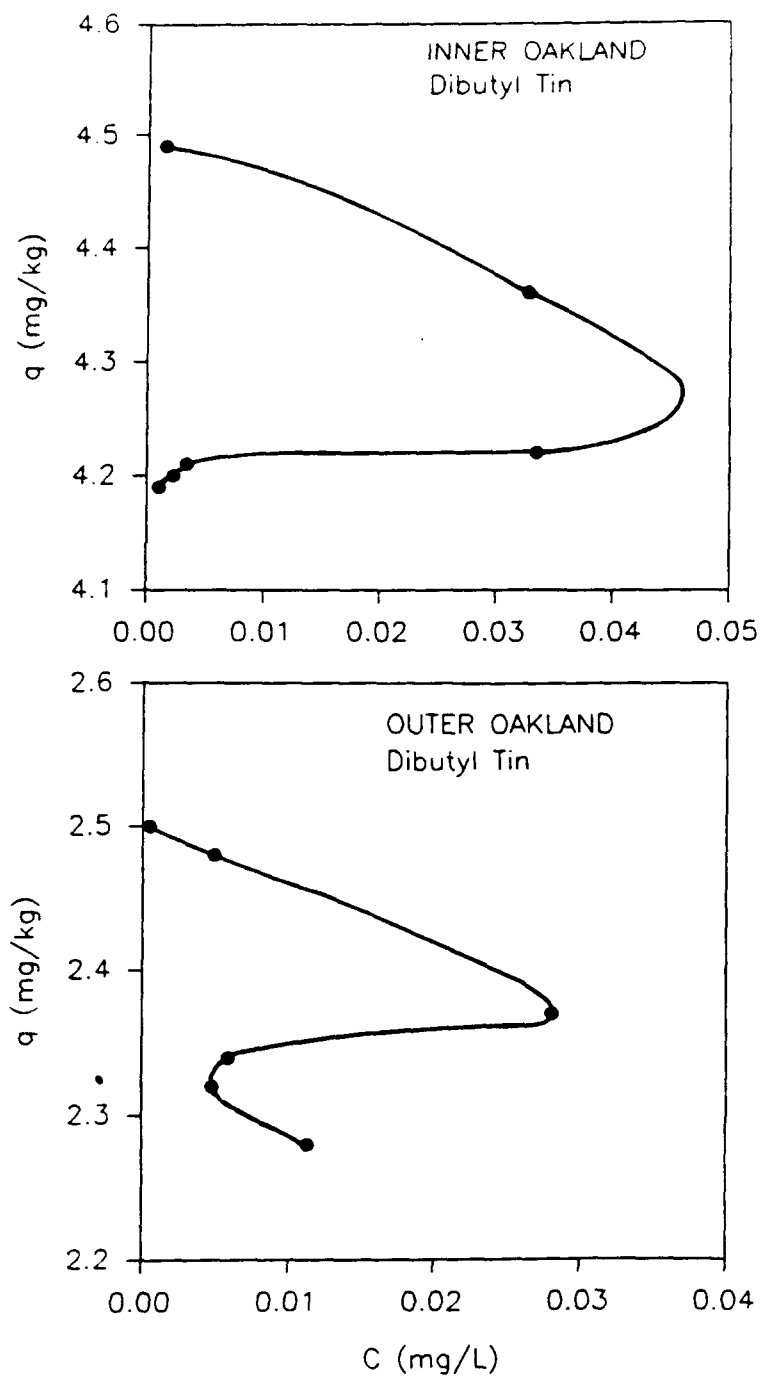


Figure V-25. Desorption Isotherms for Dibutyltin

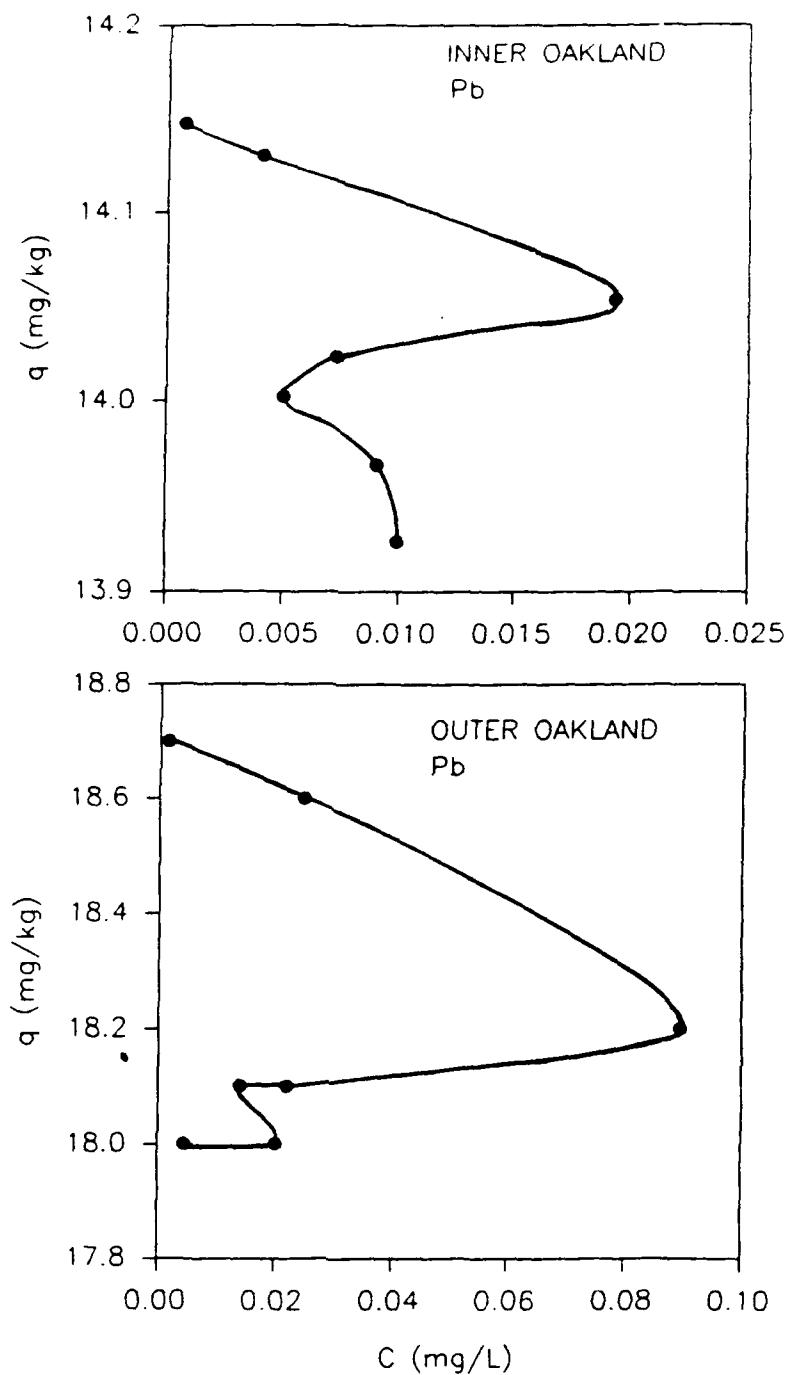
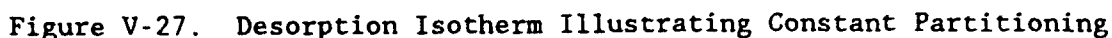


Figure V-26. Desorption Isotherms for Lead

Aerobic data. Oakland Harbor sediment did not exhibit the pronounced drop in pH following oxidation observed for other marine sediments (Environmental Laboratory 1987a and 1987b; Myers and Brannon 1988) or observed from a grab sample of Oakland Inner Harbor surface sediment used in a previous study (Brannon, Plumb, and Smith 1978). The present study used composited core samples that are different in physical and chemical characteristics from the grab samples and that are more representative of the material to be dredged.



The oxidation of Oakland Harbor sediment resulted in increased leaching of metals compared to anaerobic sediment (Tables V-24 and V-25). The increase in metals leaching was not extremely high, but leaching under aerobic conditions indicates that leachate metals concentrations will be higher if dredged material in an upland facility is drained to the extent that oxidizing conditions exist throughout the dredged material. From a management perspective, these results indicate that metals mobility can be reduced by maintaining anaerobic conditions.

Comparison of Sequential Batch and Column Leach Data

Anaerobic sequential batch and column tests were in good qualitative agreement for most contaminants in Oakland Inner and Outer Harbor sediments. Initial contaminant concentrations in column leachates tended to be higher than leachate concentrations from the first cycle of the sequential batch leach test. Peaks in batch leachate data indicating nonconstant sediment geochemistry and nonconstant distribution coefficients were confirmed as increasing contaminant concentrations in column leachate. Specific comparisons for Oakland Inner and Outer Harbor sediments are provided below:

Oakland Inner Harbor Sediment.

Silver. Initial Ag concentrations from columns were higher than in the first cycle of the batch test and the range in concentrations was larger in the column than in batch tests, but results were the same order of magnitude. The long-term trend observed during batch testing of decreasing Ag concentrations was confirmed during column testing.

Arsenic. Initial concentrations in columns were similar to concentrations in the first cycle of the batch test. The trend of increasing concentrations observed during batch testing was confirmed during column testing. The decrease in concentration following the peak concentration in batch testing was also confirmed during column test.

Cadmium. Initial Cd concentrations from the columns were higher than in the first cycle of the batch test; thereafter values were similar in the batch and column tests. The increasing concentration trend observed in batch testing was not evident in column testing.

Chromium. Concentrations of Cr from the columns were higher than those in the batch tests. Increasing Cr concentrations observed in the batch tests were confirmed during column testing.

Copper. Initial Cu concentrations from the columns were slightly higher than in the first cycle of the batch test. Thereafter values were similar in batch and column tests. Increasing Cu concentrations observed during batch testing were confirmed in 2 of 3 columns.

Mercury. Initial Hg concentrations much higher from the columns than in the first cycle of the batch test. Thereafter, values were similar in

batch and column tests. The long-term trend of very low values in batch test results was confirmed in column tests.

Nickel. Ni concentrations from columns were higher than those in the batch test. Increasing Ni concentrations observed during batch testing were partially evident during column testing but were not as well defined.

Lead. Concentrations of Pb from columns were higher than those in the batch test. Increasing Pb concentrations observed in batch testing was confirmed in 2 of 3 columns.

Zinc. Initial Zn concentrations from the columns were higher than in the first cycle of the batch test. Thereafter, values were similar in batch and column tests. Increasing Zn concentrations observed in the batch tests was not as evident during column testing.

Butyltin. Mono- and dibutyltin concentrations in column leachates were somewhat higher than mono- and dibutyltin concentrations in batch leach tests. Increasing mono- and dibutyltin concentrations followed by decreasing concentrations that were observed in batch testing was confirmed in column testing. Tri- and tetrabutyltin concentrations were generally near or below the detection limit in column and batch leachates.

PAHs. Comparison of PAHs in batch and column leach tests for Oakland Inner Harbor sediment indicates three general categories: PAHs that were below or near the detection limit in both batch and column leachates, PAHs that showed increasing concentrations in the batch test, but were below or near the detection limit in the column leachates, and PAHs for which increasing concentrations observed in batch testing was confirmed in column testing. PAH compounds in the first category were acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, chrysene, naphthalene, benzo(a)-anthracene, indeno(1,2,3-c,d)-pyrene, dibenzo(a,h)-anthracene, and benzo(g,h,i)-perylene. PAH compounds in the second category were benzo(b,k)-fluoranthene and benzo(a)-pyrene. PAH compounds in the third category were fluoranthene and pyrene.

Oakland Outer Harbor Sediment.

Silver. Initial Ag concentrations from the columns were higher than in the first cycle of the batch test. Thereafter, values were similar in batch and column tests. The long-term trend for steady then decreasing Ag concentrations in batch tests was confirmed in column testing.

Arsenic. Initial As concentrations from the columns were slightly higher than in the first cycle of the batch test. Thereafter, values were similar in the batch and column tests. Increasing As concentrations observed in batch testing was confirmed in column testing.

Cadmium. Initial Cd concentrations from the columns were higher than in the first cycle of the batch test. Thereafter, values were similar in batch and column tests. Increasing Cd concentrations observed in batch testing were confirmed in column testing.

Chromium. Initial Cr concentrations from the columns were much higher than in the first cycle of batch test. Thereafter, values were similar in batch and column tests. Increasing Cr concentrations observed in the batch tests was not confirmed in column testing.

Copper. Except for one column, initial Cu concentrations from the columns were similar to concentrations in the first cycle of the batch test. Thereafter, column concentrations were slightly higher than batch leachate concentrations. Increasing Cu concentrations observed in the batch testing was confirmed in column testing.

Mercury. Initial Hg concentrations from the columns were lower than the concentrations in the first cycle of the batch test. Thereafter, concentrations were similar in batch and column tests. Decreasing Hg concentrations observed in the batch tests was confirmed in column testing.

Nickel. Initial Ni concentrations from the columns were much higher than in the first cycle of batch test. Thereafter, values were similar in the batch and column tests. Increasing Ni concentrations observed in the batch tests was not confirmed in column testing.

Lead. Except for one column, initial Pb concentrations from the columns were similar to concentrations in the first cycle batch test. Thereafter, concentrations were similar in batch and column tests. Increasing Pb concentrations observed in the batch tests was confirmed in column testing.

Zinc. Initial Zn concentrations from the columns were much higher than in the first cycle of batch test. Thereafter, values were similar in the batch and column tests. Increasing Zn concentrations observed in batch testing was not well defined in column testing.

Butyltin. Mono- and dibutyltin concentrations in column leachates were higher than mono- and dibutyltin concentrations in batch leach tests. Increasing mono- and dibutyltin concentrations followed by decreasing concentrations observed in batch testing was confirmed in column testing. Tri- and tetrabutyltin concentrations were generally near or below the detection limit in column and batch leachates.

PAHs. Comparison of PAHs in batch and column leach tests for Oakland Outer Harbor sediment indicates that leaching of PAHs from Oakland Outer Harbor sediment differs from the leaching of PAHs from Oakland Inner Harbor sediment. Only two of three categories used to compare batch and column leaching of PAHs from Oakland Inner Harbor sediment are applicable to Oakland Outer Harbor sediment. The first category (PAHs that were below or near the detection limit in both batch and column leachates) applies to leaching of acenaphthylene, acenaphthene, and dibenzo(a,h)-anthracene from Oakland Outer Harbor sediment. None of the PAH compounds in Oakland Outer Harbor sediment fit the second category (PAHs that showed increasing concentrations in the batch test, but were below or near the detection limit in the column leachates). The third category (PAHs for which increasing concentrations observed in batch testing was confirmed in column testing) applies to leaching of fluoranthene, pyrene, chrysene, benzo(a)-anthracene, benzo(b,k)-fluoranthene, benzo(a)-pyrene, and benzo-(g,h,i)-perylene from Oakland Outer Harbor sediment. For some of the PAHs in the third category, the maximum concentration in the batch test occurred in the final cycle of the leach test. For five PAH compounds in Oakland Outer Harbor sediment (naphthalene, fluorene, phenanthrene, anthracene, and indeno(1,2,3-c,d)-pyrene) the batch leachate concentrations were low and did not show well-defined trends. The column data, however, showed well defined trends for increasing concentrations as the number of pore volumes eluted increased.

Integrated Approach

As discussed in the preceding section, there is qualitative agreement between batch and column leach test for most of the contaminants in Oakland Harbor sediments. When the batch data indicate nonconstant partitioning with peak contaminant concentrations occurring after several cycles of leaching, the column tests generally show increases in contaminant concentrations after several pore volumes have been eluted. In this section, the extent to which batch and column leach tests quantitatively agree is discussed.

An integrated approach (Figure V-28) involving predicted and observed column elution curves is used to make quantitative comparisons. In the integrated approach, information from sequential batch leach tests, soils tests, and column operation conditions are used in a contaminant transport equation to predict column elution histories. The one-dimensional contaminant transport equation for steady-flow, saturated columns on which the integrated approach is based is given below (Hill, Myers, and Brannon 1988).

$$D_p \frac{\partial^2 C_i}{\partial z^2} - V \frac{\partial C_i}{\partial z} + S = \frac{\partial C_i}{\partial t} \quad (5)$$

$$S = \frac{\rho_b}{n} \frac{\partial q_i}{\partial t} \quad (6)$$

where

D_p - dispersion coefficient for i^{th} contaminant, cm^2/sec

C_i - pore water concentration of i^{th} contaminant, mg/L

z - distance from water entrance to sediment column, cm

V - average pore water velocity, cm/sec

t - time, sec

S - interphase contaminant transfer, mg/L sec

ρ_b - bulk density, kg/L

n - porosity, dimensionless

q_i - solid phase concentration of i^{th} contaminant, mg/kg

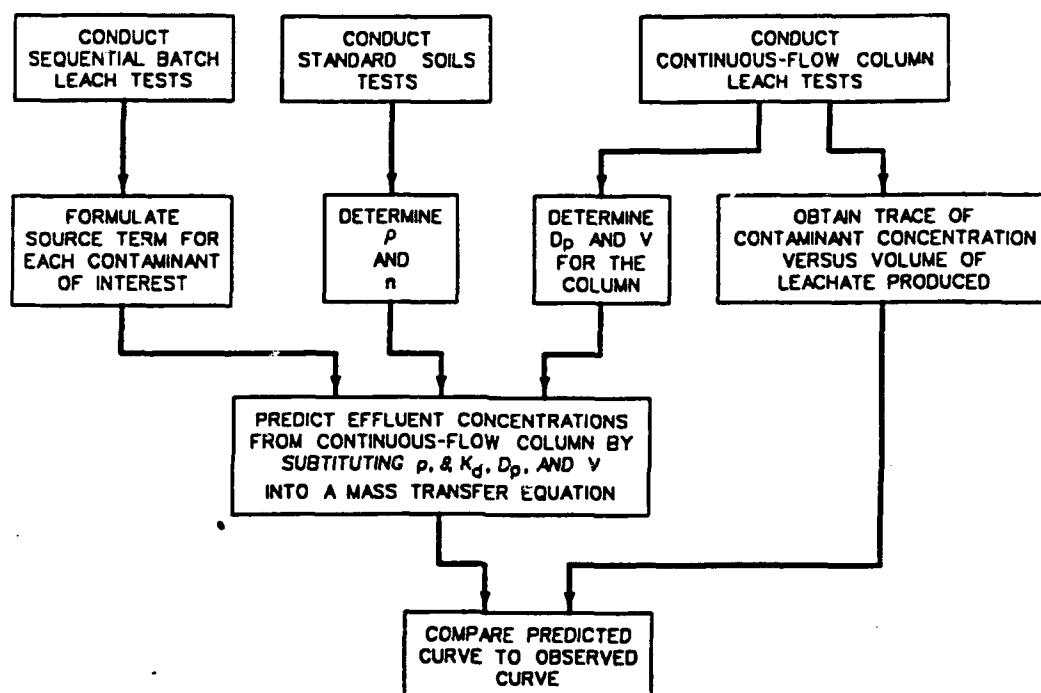


Figure V-28. Integrated Approach for Examining the Source Term

Full implementation of the integrated approach to leaching of contaminants from estuarine sediments has not been possible because a mathematical formulation of the interphase contaminant transfer term (S) for nonconstant partitioning has not been available (Myers and Brannon 1988; Palermo et al. 1989). In this report, a source term formulation that captures the main features of nonconstant partitioning is presented for the first time. Development of a complete mix equation with equilibrium-controlled nonconstant partitioning is briefly described below. As also discussed below, the complete mix equation is not applicable to Oakland Inner Harbor sediment. Thus,

application of the integrated approach to Oakland Harbor sediments was not fully successful.

Application of the local equilibrium assumption to dredged material (Myers, Brannon, and Price 1992) yields

$$q = K_d C \quad (7)$$

where

K_d = equilibrium distribution coefficient, L/kg

K_d is contaminant and sediment specific. Taking the derivative with respect to time and assuming K_d is a constant yields

$$\frac{\partial q}{\partial t} = - \frac{\partial [K_d C]}{\partial t} = - K_d \frac{\partial C}{\partial t} \quad (8)$$

Contaminant transport equations based on equations 7 and 8 are available and have been applied to leaching of freshwater sediments (Environmental Laboratory 1987a and 1987b). These models predict elution curves that monotonically decrease and, therefore, are not applicable to estuarine sediments for which contaminant concentrations do not monotonically decrease in either batch or column leach tests.

For nonconstant K_d , equation 7 is written as

$$q = K_d(T) C \quad (9)$$

where $K_d(T)$ is some function of T , the number of pore volumes eluted.

Since the nonconstant characteristic of K_d is related to salt elution (Brannon et al. 1991) and salt elution is a decaying exponential, $K_d(T)$ is written as

$$K_d(T) = K_d^f + (K_d^o - K_d^f) \exp(-\beta T) \quad (10)$$

where

K_d^o = initial distribution coefficient, that is, before salt has been washed out, L/kg

K_d^f = freshwater distribution coefficient, that is, after salt has been washed out, L/kg

β = empirical coefficient, dimensionless

Substituting into equation 9 from equation 10 for $K_d(T)$ and taking the derivative with respect to T yields

$$\frac{dq}{dT} = C\beta(K_d^o - K_d^f) - \left[K_d^f + (K_d^o - K_d^f) \exp(-\beta T) \right] \frac{dC}{dT} \quad (11)$$

Through the proper change of variable, dq/dT as given in equation 11 can be substituted into equation 6 and then into equation 5. The result, however, is a partial differential equation for which there are no published solutions. The equation could be solved numerically, but development of a numerical model for nonconstant partitioning was beyond the scope of this study. Instead, a complete mix equation was developed that includes nonconstant partitioning but neglects convective and dispersive effects in the column. The complete mix equation is

$$-C + \frac{\rho_b}{n} \frac{dq}{dT} = \frac{dC}{dT} \quad (12)$$

Substituting from equation 11 for dq/dT yields

$$\frac{dC}{dT} = \left[\frac{\left(\left[\frac{\beta \rho_b (K_d^o - K_d^f)}{n} \right] \exp(-\beta T) \right) - 1}{1 + \frac{\rho_b}{n} \left[K_d^f + (K_d^o - K_d^f) \exp(-\beta T) \right]} \right] C \quad (13)$$

For the initial condition of $C(0)=C_0$, the solution of equation 13 is

$$C(T)=C_0 \text{ EXP } \left\{ \left[\frac{A}{\beta D} + \frac{1}{\beta B} \right] \ln(B+D) - \frac{T}{B} - \left[\frac{A}{\beta D} + \frac{1}{\beta B} \right] \ln(B + D \text{ EXP } (-\beta T)) \right\} \quad (14)$$

where

$$A = \beta \rho_b (K_d^o - K_d^f)/n$$

$$B = 1 + (\rho_b K_d^f)/n$$

$$D = \rho_b (K_d^o - K_d^f)/n$$

Setting equation 13 equal to zero yields

$$T_p = \left(-\frac{1}{\beta} \right) \ln \left[\frac{n}{\beta \rho_b (K_d^o - K_d^f)} \right] \quad (15)$$

where

T_p = number of pore volumes eluted to reach the peak concentration

Model parameters for metals in Oakland Inner and Outer Harbor sediments are presented in Table V-31. Also presented in Table V-31 are T_p values predicted by equation 15. Butyltin model parameters are not presented because batch and column data did not qualitatively agree for butyltin. Model parameters were obtained by analyzing contaminant desorption isotherms obtained from the anaerobic sequential batch leach data. Desorption isotherm analysis involved finding slopes and intercepts and judgement as to what portions of the isotherms to include in the analysis. For some metals, the desorption isotherms were not well-defined, so that, model parameters could not be obtained. PAH desorption isotherms could not be analyzed for model parameters because leachate PAH concentrations were still increasing at the last cycle in the sequential batch leach test.

The predicted T_p values in Table V-31 overestimate the number of column pore volumes required for appearance of peak concentrations. The predicted peak positions for Oakland Inner Harbor sediment were especially high relative to the column data. The predictions for Oakland Outer Harbor sediment are in closer agreement with the observed data. Better agreement between

Table V-31

Model Parameters and Predicted Peak Locations

<u>Sediment/Metal</u>	<u>K_d^o</u>	<u>K_d^f</u>	<u>β</u>	<u>T_p</u>
Oakland Inner (OHI1)				
Arsenic	282	183	0.115	30.7
Cadmium	91	1.4	0.168	22.8
Chromium	589	5.6	0.120	44.5
Copper	355	8.1	0.122	39.8
Nickel	200	1.8	0.115	36.8
Lead	1995	4.4	0.159	43.3
Zinc	199	2.2	0.129	33.7
Oakland Outer (OHO)				
Arsenic	40	4.5	0.142	10.1
Cadmium	279	4.8	0.403	11.2
Chromium	525	3.3	0.339	14.7
Copper	1500	3.2	0.596	14.3
Nickel	302	4.6	0.415	11.1
Lead	10016	2.2	0.889	10.0
Zinc	498	5.6	0.431	14.1

predicted and observed for Oakland Outer Harbor sediment than for Oakland Inner Harbor sediment is to be expected since the complete mix model, as previously discussed, does a better job of predicting electrical conductivity elution for Oakland Outer Harbor sediment than for Oakland Inner Harbor sediment. Because the complete mix model with batch developed model parameters significantly overestimates peak positions on the elution curves for Oakland Inner Harbor sediment, predicted elution curves were not developed for Oakland Inner Harbor sediment.

Comparisons of predicted and observed elution curves are shown in Figures V-29 and V-30 for copper and zinc in Oakland Outer Harbor sediment, respectively. The predicted curves are based on the model parameters listed in Table V-30. The predicted and observed elution curves for these contaminants were selected for discussion because they are representative of predicted and observed elution curves for other metals.

Figure V-29 shows that the complete mix model with nonconstant equilibrium partitioning simulates the general behavior of copper elution from Oakland Outer Harbor sediment, but the rising limb of the predicted curve does not rise rapidly enough. The available column data are not sufficient to determine if the predicted location of the peak on the elution curve is accurate or if the declining limb of the predicted curve models column elution of

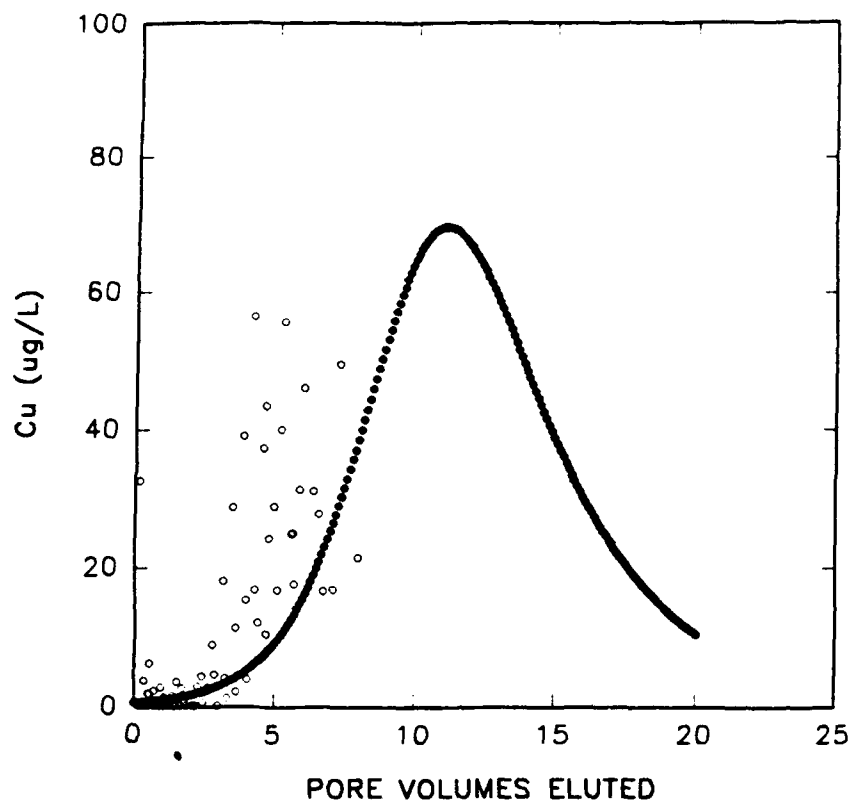


Figure V-29. Predicted and observed copper elution from Oakland Outer

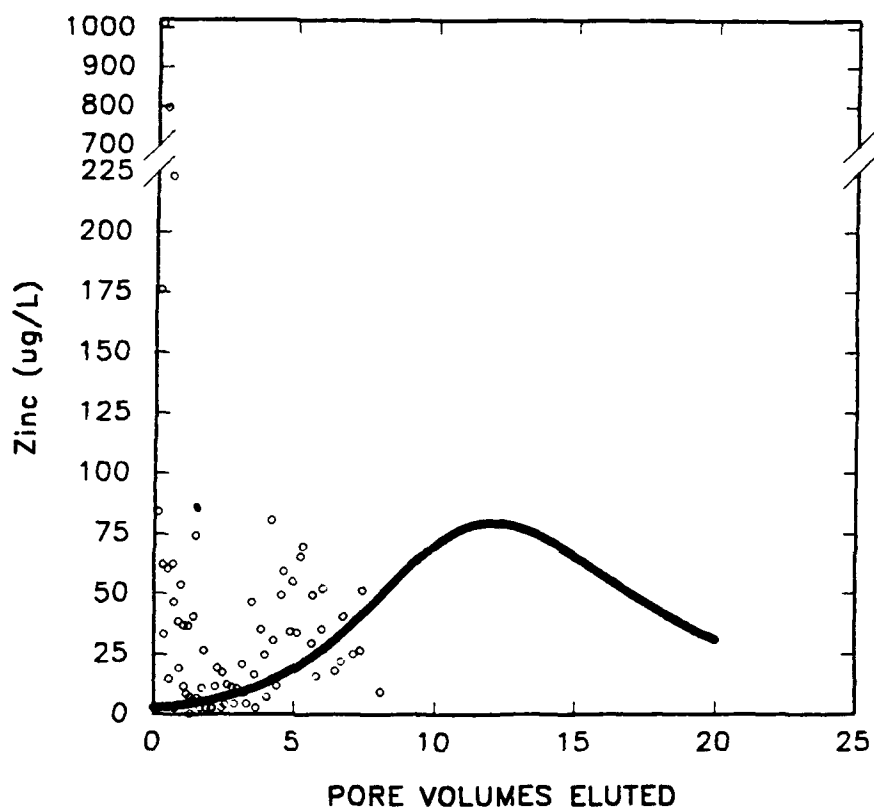


Figure V-30. Predicted and Observed Zinc Elution from Oakland Outer

copper. Other contaminants with similar predicted and observed elution curves were cadmium and lead.

Figure V-30 shows that the complete mix model with nonconstant equilibrium partitioning partially simulates the elution of zinc from Oakland Outer Harbor sediment. The tendency of zinc concentrations to increase after 2 pore volumes were eluted was simulated, but the initially high concentrations observed in column leachate were not simulated. The initial cadmium, copper, and lead concentrations were also elevated relative to the concentrations observed around 1.5 pore volumes eluted, but the differences between initial concentrations and concentrations observed later were not as large as those for zinc and nickel. As with copper, the available column data are not sufficient to determine if the predicted location of the peak on the elution curve is accurate or if the declining limb of the predicted curve models column elution of zinc. The predicted and observed elution curves for nickel were similar to those for zinc.

Figures V-29 and V-30 indicate that equation 10 may provide a basis for modeling nonconstant partitioning in estuarine sediments. The predicted and observed column elution curves show the type of nonconstant partitioning observed in the batch test. The complete mix model, however, does not adequately predict the location of peak values on the elution curves for Oakland Inner Harbor sediment. A good fit for the model could be obtained by finding column best fit parameters, but the emphasis in this study was on testing the application of parameters obtained from batch data. A solution (analytical or numerical) for equation 5 with the formulation for nonconstant partitioning given in equation 10 is needed to fully test the adequacy of the formulation.

Leachate Impacts and Controls

Leachate Flow

Leachate from dredged material placed in a disposal site is produced by three potential sources: the original pore water, or interstitial water from the dredged material, net movement of precipitation through the dredged material, and, for nearshore sites, ground water or estuary water contacting the dredged material as a result of tidal pumping. A confined disposal facility (CDF) adjoining a waterway may be affected by tidal pumping if the CDF walls are permeable. For this analysis, the assumption was made that CDFs will be sited in an upland location where tidal pumping is not a factor.

Leachate generation in a CDF depends on dredged material hydraulic conductivity, initial water content, and local hydrology. After filling, dredged material in a CDF is initially saturated (all voids are filled with water). As evaporation and seepage removes water from the voids, the amount of water stored and available for gravity drainage decreases. After some time, usually several years, a quasi-equilibrium is reached in which water that seeps or evaporates is replenished by infiltration through the surface. The amount of water stored when a quasi-equilibrium is reached and the amount of water released before a quasi-equilibrium is reached is highly dependent on local hydrology, dredged material properties, and facility design factors. To predict time-varying leachate flow, all these factors must be considered.

Preproject estimation of leachate flow, therefore, requires coupled simulation of local weather patterns and surface and subsurface processes governing leachate generation. Important climatic processes and factors include precipitation, temperature, and humidity. Important surface processes include infiltration, snowmelt, runoff, and evaporation. Important subsurface processes include evaporation from dredged material voids and flow in unsaturated and saturated zones. The Hydrologic Evaluation of Landfill Performance (HELP) model (Schroeder et al. 1988) was used to simulate these processes for selected CDF designs for Oakland Inner and Outer Harbor sediments. HELP is a hydrologic water budget model that accounts for the effects of surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage, lateral drainage to leachate collection systems, and percolation through liners.

Five alternative scenarios were selected to demonstrate use of the HELP model for estimation of percolation rates and to compare control measures for a CDF. Scenarios for CDF alternatives with 3-ft and 12-ft depths, with and without liners, and with and without caps were investigated. The alternatives are described as follows:

- a. Scenarios A1 and A2. Disposal of Oakland Inner and Outer Harbor sediments is in separate CDFs, A1 and A2, respectively. These scenarios include no controls, other than routine management of the CDF surface to provide for drainage of surface runoff. Fill depth is 12-ft and the volume of dredged material is 3.7 and 2.8 million cubic yards for Inner and Outer Oakland sediments, respectively.
- b. Scenarios B1 and B2. Scenarios B1 and B2 are the same as scenarios A1 and A2 except that dredged material is disposed in a single 3-ft lift.

c. Scenario C. Oakland Outer Harbor dredged material is placed in the bottom of the CDF to depth of 2.4 ft and a 9.6 ft layer of Oakland Inner Harbor dredged material is placed on top. Volumes are 3.7 million and 0.925 million cubic yards for Oakland Inner and Outer Harbor sediments, respectively. This scenario places the material with the lower hydraulic conductivity in the bottom of the CDF. The advantages provided by placing the material with the lower hydraulic conductivity in the bottom is partially offset by increased infiltration of rainfall through the more permeable surface material.

d. Scenario D. Oakland Inner Harbor dredged material is placed in the bottom of the CDF to a depth of 9.6 ft with a 2.4 ft layer of Oakland Outer Harbor sediment on top. Volumes are 3.7 million and 0.925 million cubic yards for Oakland Inner and Outer Harbor sediments, respectively. This scenario illustrates the benefits of a less permeable surface material.

e. Scenario E2. A leachate collection system and a composite liner are used to reduce the amount of leachate percolating through the bottom of the CDF for scenario C. The liner consists of a 1 ft thick barrier soil with a hydraulic conductivity of $1 \text{ E-}07 \text{ cm/sec}$ and a flexible membrane liner. Above the flexible membrane liner is a 1 ft layer of sand with a hydraulic conductivity of $6 \text{ E-}03 \text{ cm/sec}$. Leachate collection pipes are placed every 600 ft in the sand layer and drainage to the pipes is provided by a slope of 0.01 percent. The collected leachate could be treated on site system or transported to an appropriate wastewater treatment facility.

HELP model runs for each of these scenarios used the same basic parameters (Table V-32). Climatic data were generated for a ten year period by the model, based on historical climatic data for the San Francisco area. A Soil Conservation Service runoff curve number of 88 was used. The surface of the CDF was assumed to be devoid of vegetation. Dredged material was assumed to be saturated at the water content for the permeability point representing the highest void ratios. Hydraulic conductivities of Oakland Inner and Outer Harbor sediments as a function of void ratio are shown in Figure V-31. Dredged material placed in a disposal site will consolidate and developing lower void ratios with time. Hydraulic conductivities for Oakland Inner Harbor sediment ranged from $0.35 \text{ E-}07$ to $5.8 \text{ E-}07 \text{ cm/sec}$ and for Oakland Outer Harbor sediment from $0.83 \text{ E-}05$ to $1.3 \text{ E-}05 \text{ cm/sec}$. Lower void ratios, which represent lower water contents, produce lower hydraulic conductivities. Laboratory hydraulic conductivities at the highest void ratios were used in the analyses presented in this report, but field hydraulic conductivities could be higher. Important factors that increase field hydraulic conductivities for the total sediment mass are flow around debris and flow through zones containing high permeability materials, such as, sand and gravel. Water flowing around debris and in high permeability zones is not in as intimate contact

Table V-32

Sediment Data for Help Model Simulations

Parameter	Sediment	
	Oakland Inner (OHI1)	Oakland Outer (OHO)
Initial water content, percent	30.6	105.9
Specific gravity of solids	2.73	2.73
Hydraulic conductivity, cm/sec	1.3 E-05	5.8 E-07

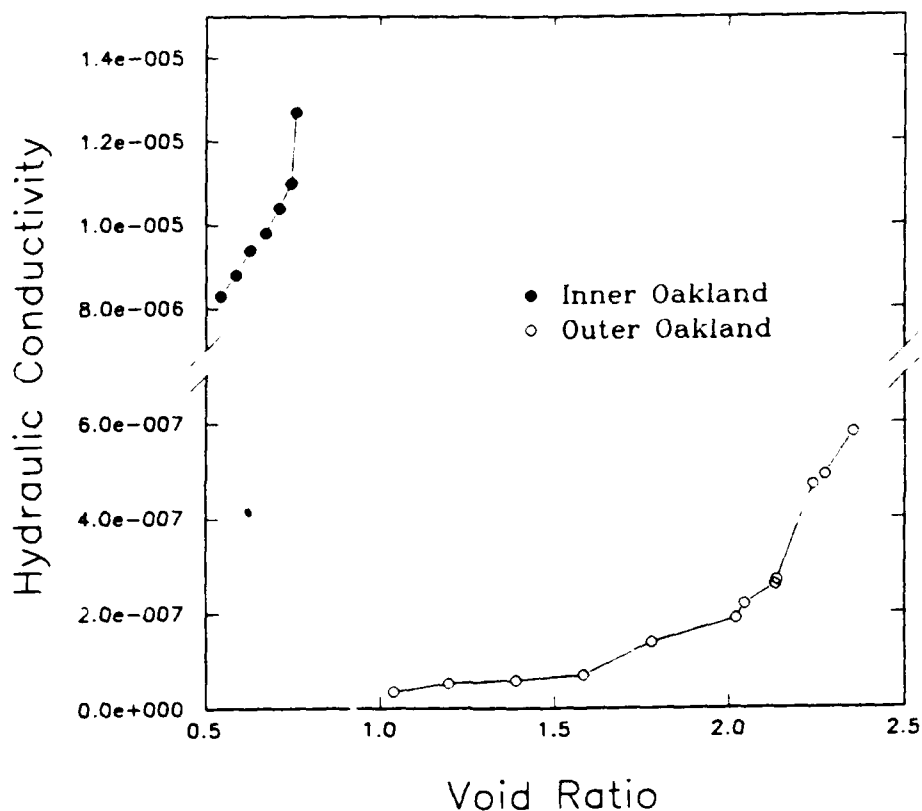


Figure V-31. Hydraulic Conductivity Versus Void Ratio

with contaminated sediment as leachate produced in laboratory leach tests. While field hydraulic conductivities may be higher than those determined in the laboratory, contaminant desorption is likely to be lower.

Figure V-32 shows the annual percolation from the base of a CDF for the first ten years of operation for scenarios A-E. The high rates during the early years are a result of drainage of pore water with the material when initially placed in the site. By the tenth year fluctuations appear to reach

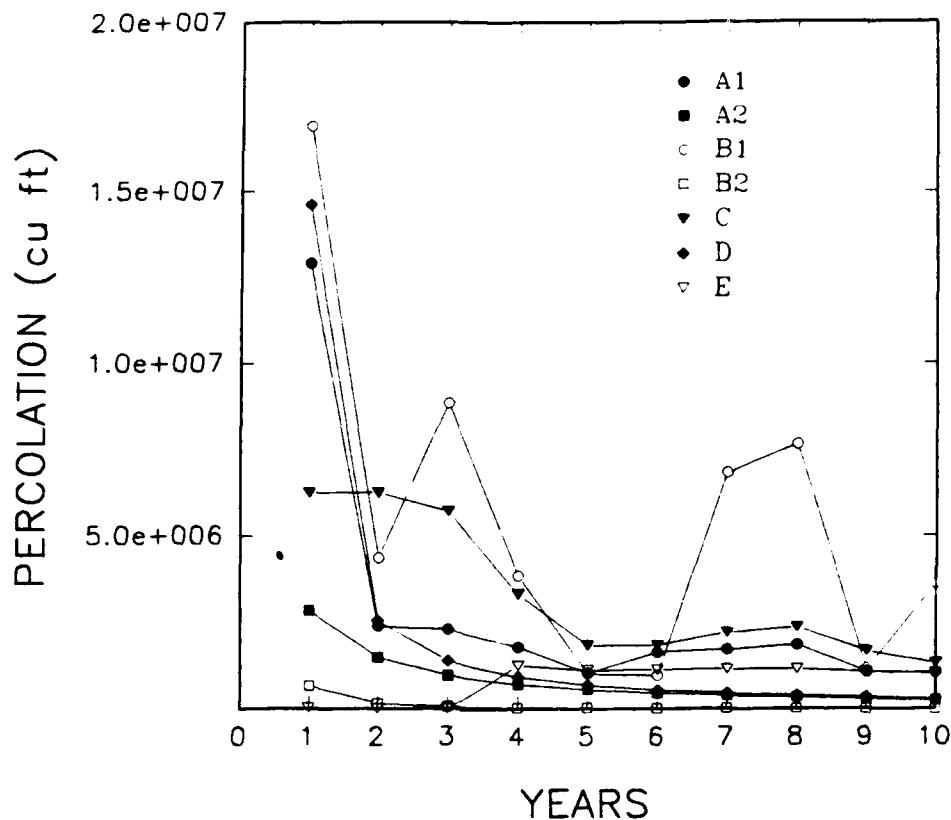


Figure V-32. HELP Model Estimates of Annual Percolation Rates

quasi-steady conditions with perturbations caused by varying climatic conditions. Scenarios A1, B1, and D have higher initial percolation rates, and scenarios B2 and E have the lowest initial percolation rates. The lined alternative (E) has the lowest initial percolation rate, but after year 4 there is little difference between this alternative and the other alternatives.

Table V-33 compares the cumulative percolation volumes from the alternative CDFs over the 10 year period. The tenth year volumes show that scenario $B > A > C > D$. HELP runs for Scenario E produced generally lower percolation volumes (Table V-33) because of effect of the liner. Also shown in Table V-33 are the effects of depth and permeability. Shallower depths provide larger surface areas for evapotranspiration and rainfall infiltration. The higher permeability material produced greater percolation volumes at 3 Ft than at 12 Ft depth. Table V-33 shows that the percolation volume from the HELP model is significantly lower than the equivalent percolation volume in one cycle of

Table V-33

Comparison of Percolation Volumes* to Batch Leach Test Equivalents

<u>Scenario</u>	<u>Percolation Volume Years 1-10 (cu ft)</u>	<u>Equivalent Volume per Cycle (cu ft)</u>	<u>Percolation Volume Years 1-10 (leach cycles)</u>	<u>Average Annual Percolation (cu ft)</u>	<u>Percolation Time for 1 Step (years)</u>
A1	2.78 E+7	4.34 E+8	0.064	2.78 E+6	156
A2	8.38 E+6	1.78 E+8	0.047	8.38 E+5	212
B1	6.59 E+7	1.08 E+8	0.610	6.59 E+6	16
B2	1.12 E+6	4.45 E+7	0.025	1.12 E+5	397
C	3.27 E+7	3.94 E+8	0.083	3.27 E+6	120
D	2.23 E+7	2.12 E+8	0.105	2.23 E+6	95
E	1.10 E+6	3.94 E+8	0.003	1.10 E+5	3580

* Based on HELP model.

the sequential batch leach test. The leaching cycle volume is based on the water content of the sediment, the volume of dredged material, and the liquid-to-solids ratio used in the batch test. The average annual percolation rate for ten year simulation period was assumed to continue at that rate for succeeding years in order to calculate the number of years of percolation equivalent to the leaching volume of the first cycle of the batch leach test. This time period ranges from 16 to 3580 years. These estimates are on the low side because as shown in Figure V-32 percolation rates in the first two years are much higher than in later years. Therefore, the total mass of contaminant released in cycles of batch leaching test is a long-term projection of contaminant loss via leaching.

Assessment of Leachate Contaminant Releases

As shown in Table V-33, worst-case leachate movement Oakland Harbor dredged material will require many years to represent a single step of the batch leaching test. Therefore, leachate quality for the first step or for interstitial water initially contained in the sediment is appropriate for comparison to regulatory limits. Tables V-34 and V-35 compare interstitial water and the first step leachate to regulatory limits issued by the California Regional Water Quality Control Board and to maximum contaminant levels (MCLs) established under the Safe Drinking Water Act. MCLs were not exceeded by any of the leachate data. Effluent or discharge limitation

Table V-34

Comparison of Leachate Concentrations ($\mu\text{g/L}$) to Regulatory Limits
for Oakland Outer Harbor Sediment (OHO)

<u>Constituent</u>	<u>Inter- stitial Water</u>	<u>Step 1 Anaerobic Leachate</u>	<u>Step 1 Aerobic Leachate</u>	<u>Maximum Contaminant Level*</u>	<u>Effluent Limits</u>	<u>Receiving Water Limits</u>
Arsenic	43	32	1.6	50	50	1
Cadmium	0.20	0.30	0.89	10	1.8	0.65
Chromium	2.0	2.4	1.2	50	16	98
Copper	46	2.6	12		9.2	6.5
Mercury	0.080	0.0070	0.016	2	2.4	0.012
Zinc	24	20	29		65	59
Tributyltin	16	0.024	0.027		0.08	0.02

* Level specified for compliance with Safe Drinking Water Act.

Table V-35

Comparison of Leachate Concentrations ($\mu\text{g/L}$) to Regulatory Limits
For Oakland Inner Harbor Sediment (OHI)

<u>Constituent</u>	<u>Inter- stitial Water</u>	<u>Step 1 Anaerobic Leachate</u>	<u>Step 1 Aerobic Leachate</u>	<u>Maximum Contaminant Level*</u>	<u>Effluent Limits</u>	<u>Receiving Water Limits</u>
Arsenic	44	1.8	0.95	50	50	1
Cadmium	0.26	0.29	2.5	10	1.8	0.65
Chromium	1.6	2.0	0.90	50	16	98
Copper	50	2.2	6.8		9.2	6.5
Mercury	0.20	0.024	0.0042	2	2.4	0.012
Zinc	39	70	65		65	59
Tributyltin	12	0.015	0.017		0.08	0.02

standards for copper and tributyltin were exceeded in at least one test for Oakland Inner and Outer Harbor sediments. Effluent limitation standards for cadmium and zinc also were exceeded for the Oakland Inner Harbor sediment. Receiving water limits were exceeded for all contaminants listed on Tables V-34 and V-35 except for chromium for both sediments and zinc in the Oakland Inner sediment.

Environmental impacts are often assessed on the basis of contaminant loss from a disposal site. Contaminant losses by leaching from Oakland Harbor sediment were estimated using leachate quality from laboratory testing and leachate flows from the HELP model. Tables V-36 and V-37 present contaminant

Table V-36
Contaminant Loss Estimates for Leachate from
Oakland Outer Harbor Sediment* (OHO)

<u>Constituent</u>	<u>Sediment Conc. mg/kg</u>	<u>Total Mass Contaminant kg</u>	<u>Leachate Conc. µg/L</u>	<u>Contaminant Loss-Yr 1 kg/yr</u>	<u>Contaminant Loss-Yr 10 kg/yr</u>
Arsenic	10	13,800	43	3.5	0.33
Cadmium	0.96	1,325	0.89	0.072	0.0068
Chromium	320	442,000	2.4	0.19	0.018
Copper	100	138,000	46	3.7	0.35
Mercury	1	1,380	0.08	0.006	0.00061
Zinc	220	303,751	29	2.3	0.22
Tributyltin	0.7	966	16	1.3	0.12

* Scenario A2, 12-ft depth and no controls.

Table V-37
Contaminant Loss Estimates for Leachate from
Oakland Inner Harbor Sediment* (OHI1)

<u>Constituent</u>	<u>Sediment Conc. mg/kg</u>	<u>Total Mass Contaminant kg</u>	<u>Leachate Conc. µg/L</u>	<u>Contaminant Flux-Yr 1 kg/yr</u>	<u>Contaminant Flux-Yr 10 kg/yr</u>
Arsenic	5.9	24,200	44	16	1.3
Cadmium	0.37	1,519	2.5	0.91	0.076
Chromium	590	2,420,000	2.0	0.73	0.061
Copper	41	168,000	50	18	1.5
Mercury	0.54	2,220	0.2	0.073	0.0061
Zinc	78	320,000	70	25	2.1
Tributyltin	0.035	144	12	4.3	0.36

* Scenario A1, 12-ft depth, no controls.

loss estimates for Outer and Inner Oakland sediment, respectively. Scenarios A1 and A2 were used for this analysis. Leachate concentrations were selected as the greatest value among the first step anaerobic leachate, first step aerobic leachate, or the interstitial water concentration. These tables illustrate the decrease in flow, and hence contaminant release, between the first and the tenth year. Comparing losses to the contaminant masses in the bulk sediment shows that a small fraction of the total mass is estimated to be lost through this pathway. Estimates from the CDF scenarios can be developed

in a similar manner to those presented in Tables V-36 and V-37 using the percolation volumes from Figure 32 or 10-year annual averages from Table V-33.

Most of the reduction in percolation volume for scenario E results from the drainage layer associated with the liner system. The HELP model indicates that the volume collected by the total leachate collected by year 10 is 2.06×10^6 cu ft. To reduce overall contaminant losses from the disposal operation, treatment of this leachate must be provided. The volume can be reduced by placement of a cover of lower permeability on top of the dredged material.

PART VI: PLANT TEST

Methods and Materials

Sediment Preparation

Upon arrival at the WES, the OH11 and OH0 sediments were each placed into one of two soil lysimeters and mixed. Enough sediment was randomly collected from each soil lysimeter using a shovel to fill one 208-1 (55-gal) steel barrel of each sediment. The sediments were placed in a walk-in cold room at 4° C until preparation for test began.

The OH11 and OH0 sediments were removed from the cold room and placed in separate aluminum drying flats, Figure II-10, on the floor of an environmentally controlled greenhouse. Each sediment was thoroughly mixed and three 19.0-1 (5-gal) samples were immediately collected and placed in new, high density polyethylene buckets with sealed lids. These were placed back in cold storage for the wetland test. Samples for chemical and physical analysis were also collected and placed in new glass bottles with teflon lined lids. The remaining sediment was allowed to air-dry with daily turning and mixing with a polypropylene shovel. After three weeks of drying, Figure II-11, the sediments were ground in a hammer mill to pass a 2-mm screen. The ground sediment was returned to its respective drying flat, mixed and samples were collected for chemical analysis. Fifty kilograms (air-dry weight) of each air-dry sediment was set aside for washing; the remainder was placed back into barrels.

One part air-dried (AD) sediment (5 kg oven-dry weight basis (ODW)) and three parts of reverse osmosis (RO) purified water (15 kg) (weight to weight basis) were placed in 19.0-liter buckets (10 buckets were needed for each sediment). The sediment/water in each bucket was then mixed for five minutes every hour for five hours using an electric mixer. The suspension was allowed to settle until all visible suspended particles had settled out and then the wash water was carefully siphoned off. A sample of the wash water was collected from each bucket and a composite of all ten buckets was collected for pH and electrical conductivity determinations. The sediments were placed back into the drying flats and the drying, grinding, and washing process was repeated until the sediment had been washed 3 times, and dried and ground 4 times.

No reference soil or sediment was provided for a comparison in the upland test. The WES reference soil (WRS1), a silt loam collected from an undisturbed woodland area at the WES, was used as a control for the upland test. The WRS1 was air-dried and ground, thoroughly mixed and samples were collected for chemical analysis. The WRS1 was not washed.

Preparation of Greenhouse Tests

A schematic diagram of the standard WES plant bioassay apparatus is shown in Figure VI-1. Four upland replicates of each air dried, unwashed sediment (to be planted with *Sporobolus virginicus*), eight replicates of air-dried, washed (ADW) sediment (four to be planted with *S. virginicus* and four to be planted with *Cyperus esculentus*) were prepared by placing 4500 g (ODW) of sediment (one 500-ml scoopful at a time) into each prepared 7.6-l Bain Marie container. Seedlings of 4 *Cyperus* and 5 *Sporobolus* were planted in pre-moistened sediment. Eight replicates of WRS1 (AD) were also prepared and planted with four replicates each of *Sporobolus* and *Cyperus*. Reagent grade nitrogen, phosphorus and potassium were added to the WRS1 to provide the minimum nutritional requirements for optimum growth.

Greenhouse Operation and Growing Techniques

The replicates were randomly placed on tables in the greenhouse. Day length of 16 hrs was maintained by using light fixtures whose face was 130 cm from the top of the 19.0-liter bucket. The 130-cm height allows maximum potential plant growth to occur without damage from the heat produced. Lights are arranged in a pattern of alternating high pressure sodium lamp and a high pressure multi-vapor halide lamp. Alternating the lamps provides an even photosynthetic active radiation (PAR) distribution pattern of 1200 μ Einsteins/ m^2/sec . The temperature of the greenhouse was maintained at $32.2 \pm 2^\circ \text{C}$ maximum during the day and $21.1 \pm 2^\circ \text{C}$ minimum at night to simulate a summer environment. Relative humidity was maintained as close to 100% as possible, but never less than 50%. Soil/sediment moisture content was maintained between 30 and 60 MPa (field capacity is 30 MPa) by adding RO water as necessary. Soil moisture tensiometers, placed in each container, were monitored daily and water added when tensiometers read greater than 60 MPa. RO water was added to the outer container up to the level of the inner container and allowed to move through holes in the bottom of the inner container. When tensiometers read less than 40 MPa, the water was siphoned from the outer container.

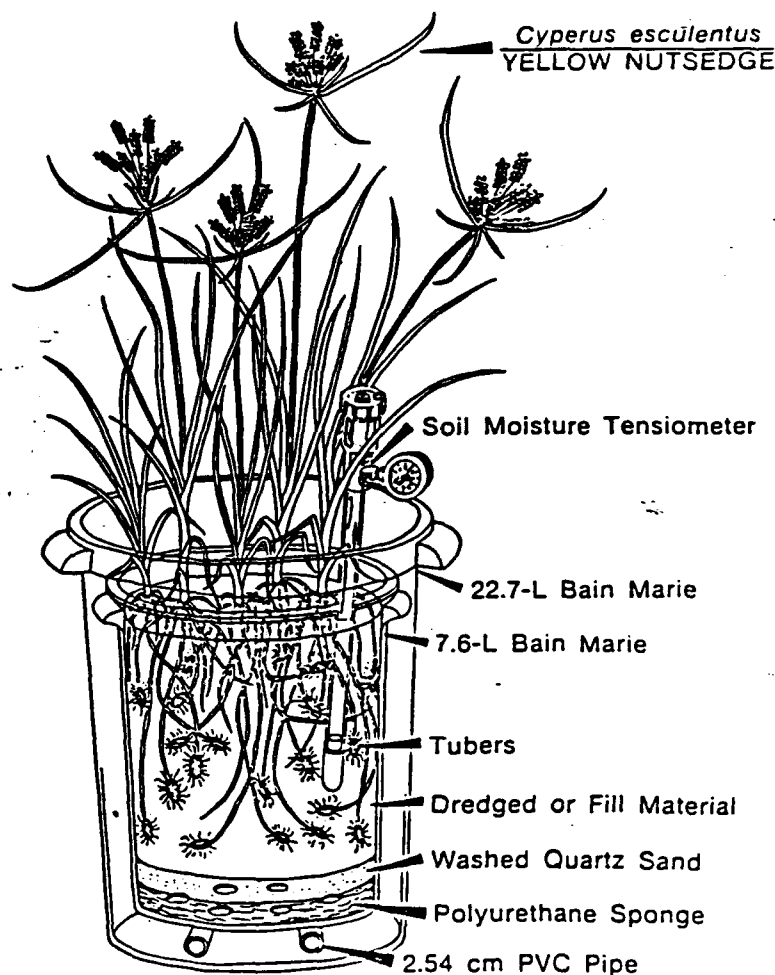


Figure VI-1. Plant Bioassay Apparatus

Plant Tissue Collection and Preparation

After 45 days *Cyperus* was harvested from each container, (*Sporobolus* was harvested after 90 days). Stainless steel scissors were used to cut the plant tissue 5 cm above the sediment/soil surface, Figure VI-2. The tissue was immediately washed in distilled water to remove any salt, sediment or dust particles and blotted dry. Total fresh weight of each replicate was then determined. Due to the low yield of *Cyperus* on the test sediments, replicates were combined on all treatments to provide enough plant tissue for all contaminant analysis. Tissue weight requirements were lowered when *Sporobolus* was harvested and replicates were combined only when necessary to provide sufficient tissue mass for all contaminant analysis. Plant tissue from replicates or combined replicates were split for heavy metals and butyltin and PAH analysis. The portion for butyltin and PAH was placed in a glass bottle with teflon closure and frozen. The heavy metals portion was dried to



Figure VI-2. Harvesting Plants After Growing in the Various Test Substrates

constant weight at 70° C in a forage drying oven to determine % plant tissue moisture and ODW yield. After drying, the tissue was ground in a small Wiley mill or with a mortar and pestle for very small samples. The ground tissue was placed in polyethylene bottles until analysis.

Electrical Conductivity and Salinity

Electrical conductivity (EC) was determined on saturated extracts of each AD and ADW sediment using the method of Rhoades (1982). The extracts were measured on a YSI model 32 conductance meter to determine EC in mmhos/cm. Salinity was also measured on the extracts using a model 10419 hand refractometer (American Optical, Buffalo, NY). EC and salinity were also determined on original wet test sediment, WRS1, and wash water samples.

Sediment pH

Ten grams (ODW to nearest 0.001 g) of original wet, AD, or ADW sediment were weighed into a tall 50-ml Pyrex glass beaker. Twenty ml of distilled water were added and the mixture was stirred with a polyethylene rod until all particles were saturated. The mixture was stirred with a magnetic stirrer for 1 min every 15 min for 45 min. After 45 min, the pH electrode was placed into the solution above the surface of the sediment and the pH was read on a pH meter (Folsom, Lee, and Bates 1981).

Organic Matter

Organic matter (OM) was determined by weight loss on ignition at 550° C on AD and ADW sediment. Procedure No. 209E (American Public Health Association 1976) was used for this test. A 5-g subsample (ODW) was weighed to the nearest 0.001 g and dried at 105 ± 2° C until constant weight (48 hr). Five grams of the oven-dried sediment is weighed to the nearest 0.001 g and combusted at 550 ± 5° C for 24 hr in a muffle furnace. The sample was allowed to cool to room temperature in a moisture desiccator and weighed to the nearest 0.001 g. Weight loss on ignition was calculated and reported as % OM using the following formula:

$$\%OM = \frac{\text{weight oven-dry sediment} - \text{weight combusted sediment}}{\text{weight oven-dry sediment}} \times 100$$

Sample Preparation and Analysis of Sediment Heavy Metals, PAH and Butyltin

Air dry and washed sediment samples, for determination of heavy metals, butyltin and PAH concentrations, were stored at 4° C in glass amber bottles with teflon closures. Sediment samples were shipped by Federal Express 24-hr delivery in heavy-duty ice chests with freeze packs to Battelle Northwest Laboratories in Sequim, WA. The samples were analyzed by Battelle for butyltin and PAH. Butyltins were analyzed by Gas Chromatography/Flame Photoionization Detection (GC/FPD) following extraction by methylene chloride. Sediment PAHs were determined by Gas Chromatography/Mass Spectrometry (GS/MS), EPA Method 8270 (USEPA 1986) following EPA Method 3540 (USEPA 1986). Six heavy metals (As, Cr, Cu, Ni, Pb and Ni) were analyzed by were measured by energy-diffusive X-Ray fluorescence (XRF) following the method of Nielson and Sanders (1983). As, Cd, and Se were analyzed by Zeeman graphite furnace atomic absorption spectroscopy (GFAA) Method 7000 Series (USEPA 1986) (Bloom and Crecelius 1984). Mercury was analyzed by cold vapor atomic absorption spectrometry (CVAAS) Method 7471 (EPA 1986) (Bloom and Crecelius 1984).

Plant Tissue Digestion and Heavy Metals Analysis

Ground plant tissue heavy metal concentrations were determined on digest of *Sporobolus* grown in test sediments and WRS1. Digests of NBS 1572 (citrus leaves) were also analyzed. An MDS-81D microwave digestion system (CEM Corporation, Matthews, NC) was used to accomplish the digests. Ten ml of nitric acid was added to 0.5 g of plant tissue and allowed to pre-digest for

30 minutes. Ten sealed sample vessels, a blank and NBS standard vessels were placed in a digestion turntable and venting tubes were connected. The turntable was set into 360° rotation and heated at 480 W for 1 min 30 sec and 300 W for 10 min. After cooling to room temperature each vessel was hand vented to release pressure and uncapped. Five ml of 30% hydrogen peroxide was added to each vessel and allowed to effervesce. When the effervescence stopped, the solution was quantitatively filtered through a Whatman # 41 filter and diluted with distilled water to 100 ml. This was analyzed by inductively-coupled plasma emission spectrometry (ICP) or direct-current plasma emission spectrometry (DCP). Mercury was determined in ground plant tissue by Cold Vapor Atomic Absorption Spectrometry (CVAAS).

Sediment and Plant Tissue Heavy Metal Concentration

Sediment and plant tissue metal concentrations were calculated by the following formula:

$$\begin{aligned} \text{metal concentration} &= \frac{\text{digest solution metal concentration} \times \text{dilution volume}}{\text{grams of ODW sediment or tissue actually digested}} \\ &= \frac{\mu\text{g/ml} \times 100 \text{ ml}}{\text{g sediment or tissue digested}} \\ &= \frac{\mu\text{g metal}}{\text{g of sediment or tissue}} \end{aligned}$$

Blanks and NBS standards were also included in the analysis. Blank concentrations were subtracted from the solution concentrations prior to using the above formula. Final concentration values were not corrected for percent recovery of NBS standards.

Butyltin and PAH Plant Tissue Preparation and Analysis

Plant tissue samples for PAH and butyltin analysis were placed in amber glass jars with teflon closures and frozen. Frozen plant tissue samples were shipped by Federal Express 24-hr delivery in heavy-duty ice chests with freeze packs to Battelle Northwest Laboratories in Sequim, WA. The samples were analyzed by Battelle for butyltin and PAH.

Results and Discussion

Effect of Air Drying and Washing on pH and EC

Oakland sediments were air-dried and washed to simulate a weathered, oxidized upland disposal environment with EC values low enough to support both holophytic and glycophytic plants. As can be seen in Table VI-1, washing the Oakland sediments reduced the pH only slightly, similar to the change in the WRS1. The simulated weathering process lowered the EC of Oakland sediments enough to a level capable of supporting glycophytic plants. The WES index plant, *Cyperus esculentus*, was shown to survive in washed Upper Oakland sediment at an EC of 11.2 mmhos/cm (Lee et al. 1992). EC values after washing were 3.2 and 9.3 mmhos/cm for the OH11 and OH0, respectively.

Table VI-1

Effect of Air Drying and Washing on Sediment pH, EC & Moisture and OM

Parameter	OH11			OH0			WRS1	
	WT	AD	ADW	WT	AD	ADW	WT	AD
pH	7.12	7.25	6.91	7.43	7.37	7.13	6.50	6.34
Moisture, %	37.9	2.24	1.40	61.4	4.79	2.53	53.3	2.13
EC, mmhos/cm	37.9	29.3	3.2	35.3	38.3	9.30	1.75	0.56
Salinity, ppt	37	29	3	35	38	9	2	0.5
OM, %	2.66	2.34	1.95	4.56	3.68	3.33	4.25	4.04

Effect of Air Drying and Washing on Total Heavy Metal Concentrations

The simulated weathering process had little effect on the total metal concentrations in the Oakland sediments from the wet to air dry to washed (Table VI-2). Since the pH of the Oakland sediments did not decrease significantly (pH of washed sediment near 7.0), metals would not be expected to become more soluble and leach during the washing process. As long as the pH in the upland environment remains near neutral, solubility of heavy metals is expected to be very limited.

Effect of Air Drying and Washing on Sediment PAH Concentrations

Mean PAH concentrations are presented in Table VI-3 for wet, air dry and air dry and washed sediments. The simulated weathering process generally had little effect on PAH concentrations in both the OH11 and OH0 sediments.

Table VI-2

Effect of Air Drying and Washing on Sediment Heavy Metal Concentrations

Parameter	OH11			OHO			WRS1	
	WT	AD	ADW	WT	AD	ADW	WT	AD
As, mg/kg	5.62 (1.21)	5.455 (0.38)	3.973 (0.17)	6.900 (0.76)	7.738 (0.53)	7.698 (0.32)	NA	3.589 (0.06)
Cd, mg/kg	0.148 (0.21)	0.170 (0.05)	0.102 (0.01)	0.233 (0.01)	0.260 (0.01)	0.208 (0.01)	NA	0.242 (0.02)
Cr, mg/kg	381.3 (55.0)	356.8 (37.34)	420.0 (34.07)	364.0 (21.4)	393.7 (19.52)	433.6 (20.36)	NA	4.642 (0.16)
Cu, mg/kg	24.53 (1.65)	23.33 (0.64)	23.83 (1.20)	31.07 (1.27)	32.83 (0.68)	32.38 (1.10)	NA	4.643 (0.33)
Pb, mg/kg	14.15 (1.38)	12.90 (0.71)	14.20 (0.81)	18.67 (1.07)	20.55 (0.81)	18.84 (0.35)	NA	10.66 (1.07)
Ni, mg/kg	65.20 (2.60)	64.48 (1.11)	64.68 (2.07)	84.03 (3.46)	86.08 (1.52)	84.90 (1.02)	NA	6.296 (0.60)
Se, mg/kg	0.173 (0.21)	0.160 (0.01)	0.150 (0.00)	0.267 (0.04)	0.262 (0.012)	0.150 (0.00)	NA	0.215 (0.01)
Ag, mg/kg	0.110 (0.01)	0.085 (0.01)	0.096 (0.00)	0.203 (0.02)	0.225 (0.02)	0.173 (0.00)	NA	0.262 (0.16)
Zn, mg/kg	61.10 (2.69)	59.9 (0.59)	62.50 (0.91)	84.80 (2.61)	90.18 (0.88)	88.54 (1.96)	NA	16.44 (1.67)
Hg, mg/kg	0.110 (0.26)	0.080 (0.00)	0.069 (0.00)	0.166 (0.01)	0.206 (0.03)	0.154 (0.01)	NA	0.103 (0.00)

Concentrations of PAH in OH11 and OHO were lower than PAH concentrations found in Twitchell Island soil (Lee et al. 1992). WRS1 soil contained only six PAHs above detection limits and three were at the same levels as the Oakland sediments.

Effect of Air Drying and Washing on Sediment Butyltin Concentrations

Mean sediment butyltin concentrations as a result of the simulated weathering process are presented in Table VI-4. The concentrations in the OH11 and OHO are much lower than in the Oakland Upper and Lower sediments from the previous Turning Basin study (Lee et al. 1992). That study indicated that butyltin was reduced mostly during the drying process probably by photolysis and microbial biodegradation. The OH11 exhibited slight reduction in

Table VI-3

Effect of Sediment Air Drying and Washing on Sediment PAH
Concentrations ($\mu\text{g/kg}$)

PAH	OH11			OHO			WRS1
	WT	AD	ADW	WT	AD	ADW	AD
Naphthalene	8.0	3.80 (0.20)	13.40 (1.03)	8.0	4.25 (0.48)	11.8 (0.25)	11.85 (2.76)
Acenaphthylene	3.3	2.00 (0.00)	8.20 (0.74)	3.3	3.00 (0.41)	9.25 (0.48)	<3.85 (0.05)
Acenaphthene	5.0	2.00 (0.00)	4.80 (0.37)	4.0	3.00 (0.41)	4.00 (0.00)	<3.85 (0.05)
Fluorene	3.0	2.00 (0.00)	4.00 (0.32)	4.0	4.25 (0.48)	4.00 (0.00)	4.75 (0.49)
Phenanthrene	24.3	15.60 (0.68)	23.20 (1.39)	23.7	22.0 (1.08)	29.3 (1.50)	27.52 (14.8)
Anthracene	7.0	4.40 (0.25)	6.60 (0.25)	8.3	8.75 (0.48)	11.8 (0.75)	<3.85 (0.05)
Fluoranthene	71.0	49.20 (4.73)	71.80 (3.84)	50.0	54.5 (2.60)	73.5 (3.71)	22.90 (12.81)
Pyrene	123.3	103.8 (5.17)	113.6 (7.12)	84.0	108.0 (8.00)	118.0 (5.21)	16.15 (8.40)
Benzo(a)- anthracene	41.7	28.40 (1.17)	31.40 (2.16)	40.0	44.5 (2.60)	42.0 (1.68)	5.30 (1.27)
Chrysene	45.0	32.20 (2.22)	46.00 (4.70)	50.3	47.3 (4.07)	51.0 (1.47)	<4.62 (0.76)
Benzofluor- anthenes	152.7	100.0 (5.01)	118.8 (7.84)	132.0	107.3 (3.34)	107.8 (3.15)	<7.78 (0.07)
Benzo(a)- pyrene	110.0	71.0 (1.79)	58.5 (3.56)	92.0	69.8 (2.18)	65.8 (1.89)	<3.85 (0.05)
Indeno(1,2,3- c,d)pyrene	86.0	51.80 (5.00)	64.80 (3.93)	91.7	48.0 (4.14)	61.5 (2.96)	<3.85 (0.05)
Dibenzo(a,h)- anthracene	17.0	11.40 (0.93)	12.00 (0.84)	14.7	16.0 (0.91)	14.0 (0.91)	<3.85 (0.05)
Benzo(g,h,i) perylene	109.7	80.80 (8.07)	86.20 (5.01)	119.7	80.3 (4.37)	77.5 (3.52)	<3.85 (0.05)

tributyltin and dibutyltin while the OHO had little reduction of tributyltin and increased in dibutyltin by an order of magnitude as a result of drying. Washing had little effect on tributyltin and dibutyltin concentrations in OH11 sediment while dibutyltin decreased in OHO. Degradation of tributyltin to dibutyltin might explain the higher dibutyltin concentrations in the OHO air dry sediment. However, in this case, reduction of tributyltin was not evident at the magnitude of the dibutyltin increase.

Table VI-4

Effect of Air Drying and Washing on Sediment Butyltin Concentrations

Butyltin	OH11			OHO			WRS1
	WT	AD	ADW	WT	AD	ADW	AD
Tetra-butyltin	<0.5 (0.06)	<1.18 (0.03)	<0.78 (0.04)	<0.6 (0.58)	<1.2 (0.02)	<1.35	<0.36
Tri-butyltin	5.07 (0.76)	2.38 (0.28)	2.25 (0.24)	2.87 (0.21)	2.3 (0.11)	1.43 (0.14)	<0.46 (0.09)
Di-butyltin	4.53 (0.55)	2.12 (0.07)	1.33 (0.16)	2.50 (0.90)	25.9 (7.12)	0.98 (0.13)	<0.36 (0.02)
Mono-butyltin	0.47 (0.12)	<1.06 (0.05)	<1.05 (0.09)	1.00 (0.63)	<1.35 (0.09)	<2.30 (1.37)	<0.72 (0.33)
Total	10.57	6.74	5.41	6.97	30.75	6.06	1.9

Plant Yield of *Sporobolus virginicus*

Yields of *Sporobolus virginicus* are present in Table VI-5. Oakland sediments were found to totally restrict growth of *Sporobolus* when air dried (Figure VI-3). Once the salts were reduced in the air dried sediments by washing, all four replicates of *Sporobolus* in both the OH11 and OHO survived. The WRS1 is shown as the control for the upland test since no reference site sediment was available for testing. Oven-dry yields in the WRS1 were significantly greater than the Oakland sediments. Oven-dry yields in the washed Oakland sediments were greater in the OHO than in the OH11.

Table VI-5

Yield of *Sporobolus virginicus*

Sediment	Status	Fresh Weight (g)	Oven-Dry Weight (g)
OH11	AD	0 (0) ^{0*}	0 (0) ⁰
OH11	ADW	5.71 (1.16) ⁴	4.56 (0.95) ⁴
OHO	AD	0 (0) ⁰	0 (0) ⁰
OHO	ADW	10.73 (0.85) ⁴	8.88 (0.70) ⁴
WRS1	AD	34.65 (5.24) ⁴	20.13 (0.67) ⁴

* Mean (standard deviation) number of replicates.

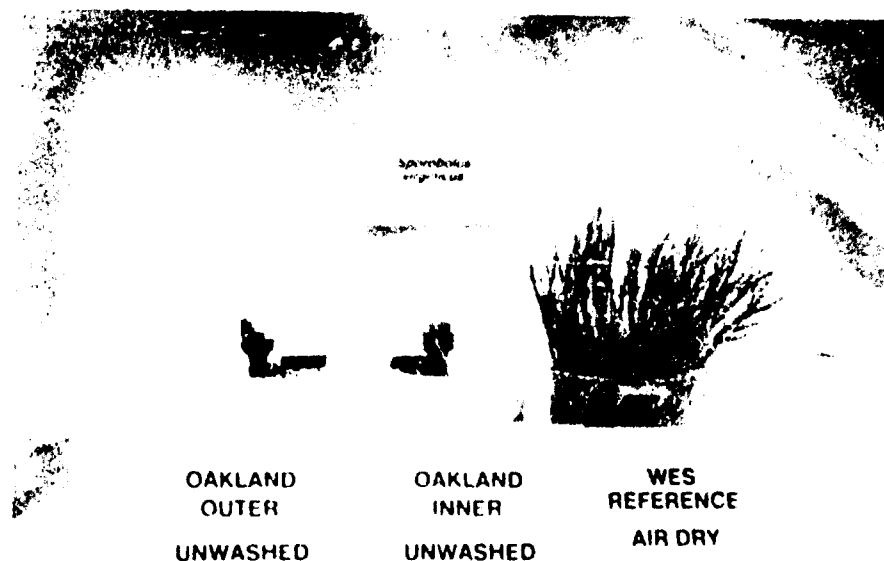


Figure VI-3. Appearance of *Sporobolus virginicus* Growing in the Various Test Substrates

Plant Yield of *Cyperus esculentus*

The WES index plant, *Cyperus esculentus*, was planted in the washed Oakland sediments only as it is a glycophyte or freshwater plant. *Cyperus* was also planted in the WRS1. Oven-dry yield of *Cyperus* was statistically higher in the WRS1 than the Oakland sediments but, not different between the Oakland sediments (Table VI-6). *Cyperus* is shown at 45 days in the Oakland sediments (Figures VI-4 and VI-5).

Table VI-6
Yield of *Cyperus esculentus*

<u>Sediment</u>	<u>Status</u>	<u>Fresh Weight (g)</u>	<u>Oven-Dry Weight (g)</u>
OH11	ADW	9.08 (0.84) ⁴	3.45 (0.32) ⁴
OH0	ADW	12.47 (2.23) ³	3.42 (0.61) ³
WRS1	AD	80.80 (7.08) ³	15.99 (1.40) ³

* Mean (standard deviation) number of replicates.

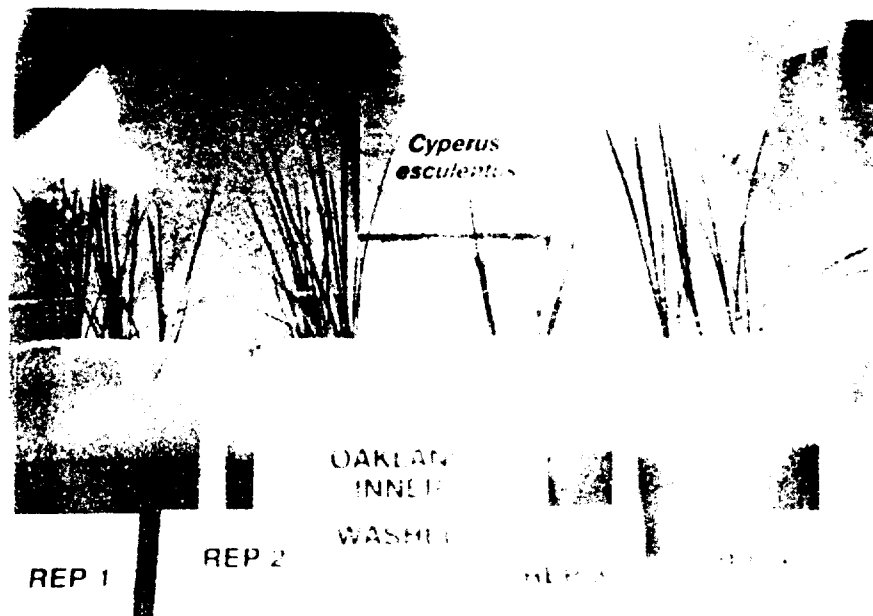


Figure VI-4. Appearance of *Cyperus esculentus* Growing in Oakland Inner Sediment

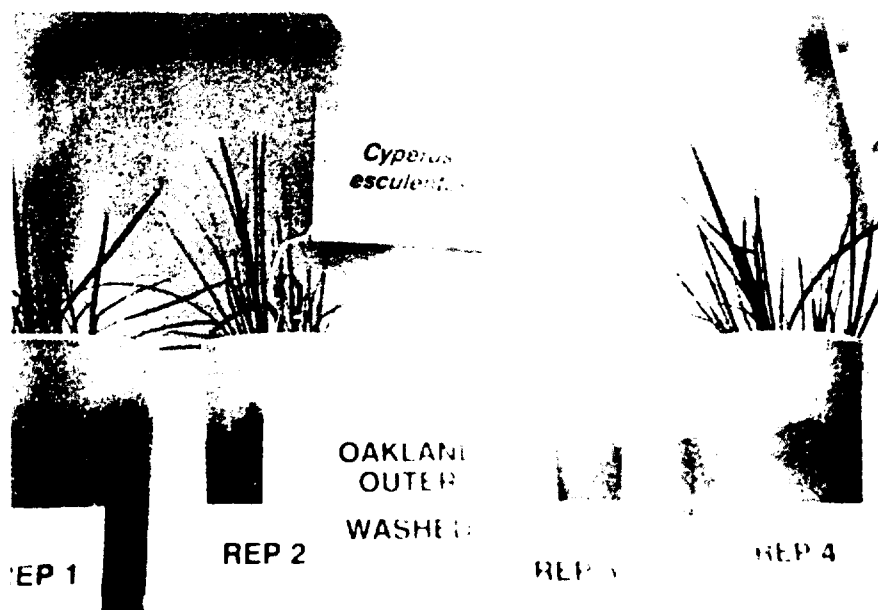


Figure VI-5. Appearance of *Cyperus esculentus* Growing in Oakland Outer Sediment

Metal Uptake by *Sporobolus virginicus*

Plant tissue content in washed Oakland sediments were generally higher in the OHO, Table VI-7. Plant tissue content of cadmium concentrations are

approaching the 0.1¹ mg/kg fresh weight action level for leafy vegetables (van Driel et al. 1985, WHO 1972) in the OHO grown *Sporobolus*. Lead is below the 1.2 mg/kg fresh weight action level for leafy vegetables. *Sporobolus* grown in Twitchell Island soil (Lee et al. 1992) contained levels of cadmium, chromium, mercury and nickel that exceeded the levels found in OH11 and OHO grown *Sporobolus*. Plant content of the other metals are at concentrations that should not be of concern. Consequently, if the Oakland Outer Harbor and Oakland Inner Harbor sediments were placed at Twitchell Island, plant contamination would not appear to be of concern for salt tolerant plants similar to *Sporobolus*. No data were available for unwashed AD sediment since no growth occurred. Total uptake (concentration x oven-dry yield) is presented in Table VI-8.

Metal Uptake by *Cyperus esculentus*

Heavy metal content of *Cyperus esculentus* grown in OHO generally appeared to be higher than in OH11 (Table VI-9). Cadmium content in *Cyperus* grown in OH11 is at the action level of 0.1 µg/g Cd (fresh weight basis) for leafy vegetables (van Driel et al. 1985, WHO 1972). Dutch action levels in mixed animal feeds are 1.0 mg/kg dry weight (European Community 1974). Cadmium content exceeds this action level in OHO as well as in the WRS1. *Cyperus* previously grown in Twitchell Island soil also exceeded this action level with 3.59 µg/g of cadmium (Lee et al. 1992). However, the cadmium concentrations in Oakland sediments and WRS1 falls in the median range of 0.2 mg/kg background levels found in surface soils (Holnigren et al. 1987). Plants demonstrated no adverse effect from tissue cadmium concentrations ranging from 0.1-1.0 mg/kg (dry weight basis) and tissue concentrations of 3 to 10 mg/kg (dry weight basis) were reported to be phytotoxic (Chaney 1983). The limitation on soil cadmium concentrations to minimize plant uptake is 2.5 mg/kg (USEPA 1979). Although the test sediments are an order of magnitude below this level, uptake in *Cyperus* did reach levels that would be of concern to some world communities.

The cadmium data for *Cyperus* can be used to predict potential uptake of cadmium by other plants using the relationship developed by van Driel et al. 1985 shown in Figure IV-6. Accordingly, a concentration of 2.187 mg/kg (dry weight) cadmium in *Cyperus* grown on OHO would translate to a potential of

¹ 0.1 mg/kg fresh weight approximately corresponds to 1.0 mg/kg on an oven-dry weight basis.

Table VI-7

Heavy Metal Concentration in *Sporobolus virginicus* ($\mu\text{g/g}$ dry wt)

<u>Parameter</u>	<u>OHI1</u>		<u>OHO</u>		<u>WRS1</u>
	<u>AD</u>	<u>ADW</u>	<u>AD</u>	<u>ADW</u>	<u>AD</u>
Arsenic	PD ¹	<0.991	PD	<0.995	<0.992
Cadmium	PD	0.251	PD	0.677	0.144
Chromium	PD	<0.991	PD	<0.995	<0.992
Copper	PD	6.999	PD	9.552	2.332
Lead	PD	0.197	PD	3.383	<1.821
Nickel	PD	0.991	PD	1.692	<1.240
Selenium	PD	<0.991	PD	<0.995	<0.246
Silver	PD	0.000	PD	<0.996	0.000
Zinc	PD	17.23	PD	41.78	2.292
Mercury	PD	<0.030	PD	<0.030	<0.028

¹ Plant death.

Table VI-8

Total Heavy Metal Uptake in *Sporobolus virginicus* ($\mu\text{g/pot}$ dry weight)

<u>Parameter</u>	<u>OHI1</u>		<u>OHO</u>		<u>WRS1</u>
	<u>AD</u>	<u>ADW</u>	<u>AD</u>	<u>ADW</u>	<u>AD</u>
Arsenic	PD ¹	<4.52	PD	<8.84	<19.96
Cadmium	PD	1.14	PD	6.01	2.90
Chromium	PD	<4.52	PD	<8.84	<19.97
Copper	PD	31.9	PD	84.8	46.94
Lead	PD	0.90	PD	30.04	<36.66
Nickel	PD	4.52	PD	15.02	<24.96
Selenium	PD	<4.52	PD	<8.84	<4.95
Silver	PD	0.000	PD	<8.84	0.000
Zinc	PD	78.57	PD	371.0	46.14
Mercury	PD	<0.14	PD	<0.27	<0.56

¹ Plant death.

Table VI-9

Heavy Metal Concentration in *Cyperus esculentus*¹ ($\mu\text{g/g}$ dry weight)

Parameter	<u>OH11</u>	<u>OHO</u>	<u>WRS1</u>
	<u>ADW</u>	<u>ADW</u>	<u>AD</u>
Arsenic	<1.000	<0.994	<0.993
Cadmium	1.000	2.187	1.715
Chromium	<1.000	<0.994	<0.993
Copper	8.000	10.34	8.477
Lead	0.200	3.976	0.133
Nickel	2.400	1.193	1.788
Selenium	<1.000	14.71	0.000
Silver	0.000	3.419	0.000
Zinc	62.20	100.4	73.83
Mercury	<0.030	<0.030	0.030

¹ Concentrations determined from one digest solution of composited replicates.

Wet weight basis is approximately 1/10 dry weight value.

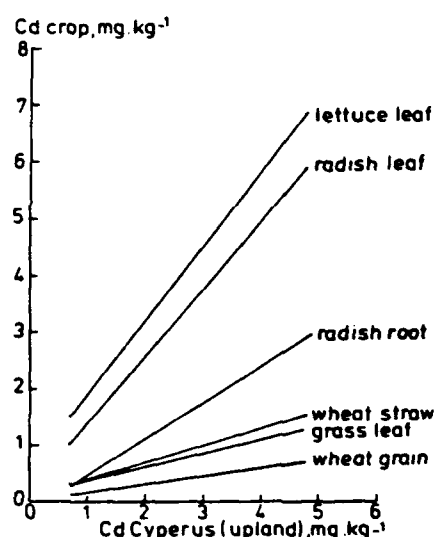


Figure VI-6. Relationship Between Cd in *Cyperus* Leaves (Upland) and in Lettuce, Radish, Spring Wheat, and Red Fescue Grass

approximately 2.5 and 3.5 mg/kg (dry weight) in radish leaves and lettuce, respectively, should these crops be grown on OHO placed in an upland environment. These tissue cadmium contents would be a human health concern to the Dutch.

Tissue lead is below the 1.2 mg/kg fresh weight action level for leafy vegetables in plants grown in both Oakland sediments, although plant tissue lead appears to be higher for OHO compared to OH11. Total uptake of lead in

OHO plants was higher than WRS1 plants indicating more mobility of lead from OHO sediment into plants (Table VI-10). *Cyperus* selenium and silver

Table VI-10

Total Heavy Metal Uptake in *Cyperus esculentus* ($\mu\text{g}/\text{pot}$ dry weight)

<u>Parameter</u>	<u>OHI1 ADW</u>	<u>OHO ADW</u>	<u>WRS1 AD</u>
Arsenic	<3.45	<3.40	<15.88
Cadmium	3.45	7.487	27.42
Chromium	<3.45	<3.40	<15.88
Copper	27.6	35.36	135.55
Lead	0.69	13.60	2.13
Nickel	8.28	4.08	28.59
Selenium	<3.45	50.30	0.000
Silver	0.000	11.69	0.000
Zinc	214.59	343.4	1180.5
Mercury	<0.10	<0.10	0.48

concentrations appear to be elevated in the OHO. Since plant growth was poor in each sediment from Oakland Harbor, all replicates were composited to give a sufficient amount of tissue to chemically analyze. Total uptake of cadmium, copper, nickel, and zinc were higher in WRS1 than from the Oakland Sediments (Table VI-19) suggesting more overall mobility of these metals in the WRS1 reference soil. However, tissue contents of cadmium, lead, and selenium appear to be elevated in plants grown in OHO and therefore should be of concern. Because of the need to composite replicate plant tissue in the present tests, additional plant bioassays should be conducted with more replication to provide sufficient plant tissue to conduct replicated analyses to verify these elevated tissue concentrations. However, in light of the results of the present evaluation, restrictions and controls for plants colonizing OHO in an upland disposal environment should be considered. PAH Uptake by *Sporobolus virginicus*. Mean PAH concentrations in *Sporobolus virginicus* are presented in Table VI-11 on a wet weight basis. No PAH data were available for AD unwashed OHI1 and OHO as no growth occurred. PAH concentrations in *Sporobolus* grown in ADW sediment were generally below

detectable limits or just detectable for naphthalene, phenanthrene, and fluoranthene. Concentrations appeared to be slightly higher in *Sporobolus* grown in OH0 sediment than the OH11 sediment, but were in the same range as *Sporobolus* grown in the WRS1.

Total plant uptake ($\mu\text{g}/\text{kg}$ wet weight \times total fresh weight of plant tissue per pot) is shown in Table VI-12. Only PAHs determined above detection limits are listed. Since concentrations in *Sporobolus* grown in Oakland sediments are in the range of *Sporobolus* grown in WRS1, total uptake is much higher in WRS1 grown *Sporobolus* due to the substantially higher yield. These data suggest plant uptake of PAH from Oakland Harbor Sediments are lower than that observed in the test reference and should not be of concern.

PAH Uptake by *Cyperus esculentus*

Cyperus esculentus PAH concentrations are shown in Table VI-13. As with *Sporobolus*, *Cyperus* concentrations of PAHs were mostly below detection limits. Phenanthrene was found above detectable limits in OH11, OH0 and WRS1 grown *Cyperus* in the range of 5 $\mu\text{g}/\text{kg}$ wet weight.

Fluoranthene was found above detection limits only in OH0-grown *Cyperus*

Total PAH uptake by *Cyperus esculentus* is presented in Table VI-14 for PAHs with above detection limit values (phenanthrene and fluoranthene). The lower yield of *Cyperus* in the Oakland sediments results in less total uptake of phenanthrene compared to the WRS1.

If Oakland sediments are placed in an upland environment and plant colonization occurs, PAH uptake by plants will be minimal and should not be of concern.

Butyltin Uptake by *Sporobolus virginicus*

Mean butyltin concentrations in *Sporobolus virginicus* are presented in Table VI-15. Due to the low mass of plant tissue available, detection limits were higher for butyltins and reported on a wet weight basis. None of the *Sporobolus* grown in Oakland sediments or WRS1 had concentrations of butyltins above method detection limits (MDL). Tributyltin was detected below MDL in OH11 and WRS1 at 8.5 and 11.2 $\mu\text{g}/\text{kg}$ wet weight respectively. On a dry weight basis these concentrations would be 11.1 and 16.04 $\mu\text{g}/\text{kg}$ (dry weights of samples are provided in Appendix E). These values are higher than tributyltin <4.6 $\mu\text{g}/\text{kg}$ dry weight concentrations in *Sporobolus* grown in Twitchell Island soil (Lee et al. 1992). Tributyltin concentrations were slightly lower in Oakland Upper and Lower AD sediments, 1.67 and 3.1 $\mu\text{g}/\text{kg}$ dry weight, and 1.747

Table VI-11

PAH Concentration in *Sporobolus virginicus* ($\mu\text{g/kg}$ wet weight)

<u>Parameter</u>	<u>OH11</u>		<u>OHO</u>		<u>WRS1</u>
	<u>AD</u>	<u>ADW</u>	<u>AD</u>	<u>ADW</u>	<u>AD</u>
Naphthalene ^b	PD ¹	<6.34	PD	8.75 (1.82) ²	12.59 (10.19)
Acenaphthylene	PD	<4.33	PD	<7.20 (0.39)	2.30 (0.52)
Acenaphthene	PD	<2.43	PD	<3.48 (0.05)	<1.50 (0.14)
Fluorene	PD	<2.18	PD	<2.31 (0.34)	<1.27 (0.22)
Phenanthrene	PD	10.59	PD	12.27 (1.99)	6.07 (0.29)
Anthracene	PD	<1.09	PD	<1.71 (0.27)	<1.01 (0.25)
Fluoranthene	PD	2.92	PD	3.69 (0.36)	2.74 (0.19)
Pyrene	PD	<2.59	PD	<2.89 (0.15)	2.18 (0.21)
Benzo[a]anthracene	PD	<0.77	PD	<2.93 (2.10)	<0.27 (0.01)
Chrysene	PD	<1.28	PD	<1.60 (0.00)	<0.94 (0.03)
Benzo[b]fluoranthene	PD	<4.69	PD	<5.43 (0.30)	<1.79 (0.41)
Benzo[k]fluoranthene	PD	<0.93	PD	<4.55 (0.25)	<0.10 (0.04)
Benzo[a]pyrene	PD	<0.09	PD	<4.73 (0.27)	<0.19 (0.04)
Indeno[1,2,3-c,d]pyrene	PD	<0.91	PD	<5.68 (0.31)	<0.62 (0.05)
Dibenzo[a,h]anthracene	PD	<3.34	PD	<3.87 (0.21)	<1.78 (0.03)
Benzo[g,h,i]perylene	PD	<6.66	PD	<7.70 (0.43)	<4.05 (0.45)

^b Blank corrected.¹ Plant death.² Standard deviation of mean.

and <3.0 $\mu\text{g/kg}$ in the ADW sediment and were not considered a problem in the upland environment. However, these values were detected above MDL and have better validity than the OH11 and WRS1 that were detected below MDL. Also, since the WRS1 *Sporobolus* had higher concentrations of tributyltin than the OH11, these concentrations are not considered to be an environmental concern.

Table VI-12
Total PAH Uptake in *Sporobolus virginicus*

<u>Parameter</u>	<u>OHI1</u>		<u>OHO</u>		<u>WRS1</u>
	<u>AD</u>	<u>ADW</u>	<u>AD</u>	<u>ADW</u>	<u>AD</u>
Naphthalene ^b	PD ¹	<36.20	PD	93.89	436.24
Phenanthrene	PD	60.47	PD	131.66	210.33
Fluoranthene	PD	16.67	PD	39.59	94.94

* Only PAHs above detectable limits are listed.

¹ Plant death.

Table VI-13
PAH Concentration ($\mu\text{g/kg}$, wet weight) in *Cyperus esculentus*

<u>Parameter</u>	<u>OHI1</u>	<u>OHO</u>	<u>WRS1</u>
	<u>ADW</u>	<u>ADW</u>	<u>AD</u>
Naphthalene ^b	<3.98	<2.78	<2.72
Acenaphthylene	<3.90	<1.83	<1.75
Acenaphthene	<1.35	<1.02	<1.44
Fluorene	<1.06	<1.06	<0.78
Phenanthrene	5.26	5.24	4.25
Anthracene	<1.19	<0.73	<0.67
Fluoranthene	<1.11	1.19	<0.76
Pyrene	<1.43	<1.42	<0.84
Benzo[a]anthracene	<0.62	<0.36	<0.17
Chrysene	<0.80	<0.42	<0.24
Benzo[b]fluoranthene	<2.94	<0.57	<2.02
Benzo[k]fluoranthene	<0.47	<0.73	<0.69
Benzo[a]pyrene	<0.57	<0.80	<0.76
Indeno[1,2,3-c,d]pyrene	<0.08	<0.15	<0.11
Dibenzo[a,h]anthracene	<2.09	<1.46	<1.43
Benzo[g,h,i]perylene	<1.18	<2.92	<1.61

^b Blank corrected.

Table VI-14
Total PAH Uptake (g/pot, wet weight) in *Cyperus esculentus**

<u>Parameter</u>	<u>OHI1</u>	<u>OHO</u>	<u>WRS1</u>
	<u>ADW</u>	<u>ADW</u>	<u>AD</u>
Phenanthrene	47.76	65.34	343.40
Fluoranthene	<10.08	14.84	<61.41

* Only PAHs above detectable limits are listed.

Table VI-15

Butyltin Concentration ($\mu\text{g/kg}$, wet weight) in *Sporobolus virginicus*

<u>Parameter</u>	<u>OHI1</u>		<u>OHO</u>		<u>WRS1</u>	<u>METHOD</u>
	<u>AD</u>	<u>ADW</u>	<u>AD</u>	<u>ADW</u>	<u>AD</u>	<u>BLANK</u>
Tributyltin	NS	<8.5J ¹	NS	<38.3 (0.00) ^{2*}	<31.525J (6.775) ⁴	<38.3
Dibutyltin	NS	<18.1	NS	<18.1 (0.00) ²	18.1 (0.00) ⁴	<18.1
Monobutyltin	NS	<16.4	NS	<16.4 (0.00) ²	<32.10J (2.75) ⁴	38.4

¹ Values with a J indicate that analyte was detected below method detection limit.

* Superscript numerals indicate mean (standard deviation) no. of replicates.

Butyltin Uptake by *Cyperus esculentus*

Cyperus uptake of butyltins is presented in Table VI-16. Due to the low mass of plant tissue available, detection limits were higher for butyltins and reported on a wet weight basis. For the most part, all butyltins were below detection limits except for one sample. *Cyperus* grown on OHI1 sediment contained 100.9 $\mu\text{g/kg}$ wet weight tributyltin or 487.4 $\mu\text{g/kg}$ dry weight. This value seems somewhat out of line with the accompanying results, but it could be correct. This value is being checked for accuracy and will be verified as soon as possible.

Table VI-16

Butyltin Concentration ($\mu\text{g/kg}$, wet weight) in *Cyperus esculentus*

<u>Parameter</u>	<u>OHI1</u>		<u>OHO</u>		<u>WRS1</u>	<u>METHOD</u>
	<u>AD</u>	<u>ADW</u>	<u>AD</u>	<u>ADW</u>	<u>AD</u>	<u>BLANK</u>
Tributyltin	PD ¹	100.9	PD	<38.3	<38.3	<38.3
Dibutyltin	PD	<18.1	PD	<18.1	<18.1	<18.1
Monobutyltin	PD	<16.4	PD	<16.4	<16.4	<16.4

¹ Plant death.

Impacts and Recommendations

If Oakland Harbor Inner and Outer sediments are placed in a upland environment, plant colonization of even salt tolerant upland plants are not expected until sufficient salts are leached. Once Oakland sediments can support freshwater upland plants, uptake and bioavailability of cadmium may be of concern. Plants should be limited to non-agricultural species that minimize uptake, such as red fescue.

Oakland Outer sediment had elevated concentrations of selenium and silver that are of concern. However, since these elevated concentrations were determined from one composite plant sample and only in OH11, further evaluation and additional bioassay tests need to be conducted to verify these results. Upland disposal of Oakland sediments are not expected to contribute to plant uptake of PAH and butyltin that would be of environmental concern.

PART VII: ANIMAL TESTS

Methods and Materials

A supply of red wiggler earthworms, *Eisenia foetida*, was obtained from a commercial bait supplier, Briggs Bait Farm, Meridian, MS. The worms were transferred to a horse manure holding medium until used for bioassessments. The horse manure selected for the worm medium was collected from a single horse that was neither on medication nor fed materials containing contaminants above background levels. In all bioassessments, only mature, clitellate earthworms were used.

Sediments were washed, as previously described in Section VI. Samples of the Oakland Inner and Outer Harbor sediments were collected for earthworm toxicity screening tests. Three earthworms were placed in small amounts of each of the test substrates and survival after 72 hours was observed. The results of the toxicity screening tests were similar to Lee et al. 1992 (Table 57) and used to determine the point in the washing at which the salt concentration was low enough for earthworms to colonize and allow the earthworm bioassessment procedure to be conducted.

The WES earthworm bioassessment procedure was designed to evaluate the potential toxicity or mobility of contaminants to soil invertebrates colonizing a sediment or soil in an upland environment. The test materials were placed in transparent plexiglass cylinders 12 inches (30 cm) deep and 6 inches (15 cm) in diameter (Figure VII-1). Each cylinder was closed at one end with cotton muslin cloth or Nytex mesh and filled the test substrate. The muslin covered end of each cylinder was placed in an 8-inch (20-cm) diameter plastic dish of deionized water. The water could then diffuse into the substrate and the earthworms, could move to areas of optimum moisture.

Five substrates replicated three times were used in the toxicity/contaminant mobility bioassessment; Oakland Inner Harbor Sediment (OHI1),

Oakland Outer Harbor Sediment (OHO), and Manure Reference (horse manure worm-culture and holding media). Two Field Verification Program (FVP) substrates were selected as additional references. These references serve as examples of a highly contaminated marine sediment following upland disposal to provide perspective in the interpretation of the Oakland substrate bioassay data. FVP1 (Contaminated Reference 1) was material that had remained unvegetated since disposal in 1984, and FVP2 (Contaminated Reference 2) represented

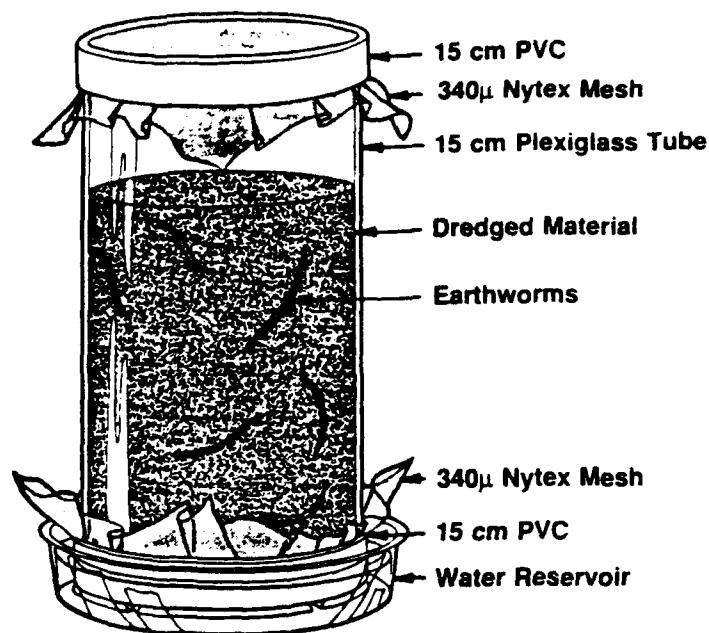


Figure VII-1. Earthworm Bioassay Apparatus

the same substrate after the addition of amendments in the field to establish vegetation. The FVP Upland Site is summarized in Folsom et al. (1988) and in Brandon et al. (1991).

Fifty earthworms were added to each cylinder (Figure VII-2). After 28 days the cylinders were emptied and the worms were recovered (Figures VII-3 and VII-4). The earthworms from each cylinder were counted and weighed before and after depurating on moist filter paper for 24 hours. Earthworms were humanely killed by freezing in preparation for analysis.

Frozen worms were shipped overnight to the analytical laboratory and analyzed for metals, pesticides, PCBs, and PAHs. Analytical preparations and procedures are discussed in Lee et al. 1992.

Results and Discussion

The results of the preliminary toxicity screening tests indicated that the Oakland Harbor substrates would not permit the colonization by upland (freshwater) soil invertebrates unless salt levels were reduced to levels osmotically safe. As anticipated, salty, unwashed Oakland Inner and Outer Harbor sediments were toxic to earthworms, but test animals survived in both substrates after washing. Neither the Oakland Inner Harbor nor the Oakland Outer Harbor substrate was toxic after washing, although worm growth and



Figure VII-2. Initial Earthworm Biomass



Figure VII-3. Earthworm Test after 28 Days

number of individuals recovered varied with the substrates (Table VII-1). Low tissue weights required the replicates to be composited to increase the amount of tissue to 20 grams fresh weight for analysis of metals, PAHs and PCBs. The results of the chemical analysis of the test earthworm tissues are



Figure VII-4. Harvesting Earthworms

summarized in the following tables: metals, Table VII-2; PCBs, Table VII-3; PAHs, Table VII-4; and pesticides, Table VII-5.

The initial toxicity tests indicated that the sediments from both Oakland Inner and Outer Harbors were not toxic after washing and that colonization by upland invertebrates could begin relatively soon after disposal in an upland environment where salt would be washed away and not accumulate. Any colonization is, however, limited by the presence of adequate food material for the soil invertebrate community. In the absence of a concomitant plant community the successful colonization of a dredged material disposal site by upland invertebrates is unlikely. This is clearly shown in Table VII-1 where the weights and numbers of the recovered earthworms are tabulated. The manure reference material, a good earthworm holding medium, shows both good earthworm recovery and favorable weight gain. In contrast, test substrates OH0 and OH1!, suggest that the introduced test population is on the decline. These data indicate the failure of the Oakland Harbor substrates to provide the

Table VII-1
Earthworm Toxicity Test (28-Day) of Reference Manure,
Oakland Inner and Outer Harbor Sediments

<u>Substrate</u>		<u>Original Number of Worms</u>	<u>Final Number of Worms¹</u>	<u>Wet Weight (g)</u>
OHI1	1	50	50	5.98 ²
OHI1	2	50	50	5.08 ²
OHI1	3	50	49	5.21 ²
OHI1	4	50	53	5.35 ²
OHO	1	50	47	5.12 ³
OHO	2	50	45	4.79 ³
OHO	3	50	51	5.03 ³
OHO	4	50	48	5.00 ³
FVP1	1	50	33	4.13 ⁴
FVP1	2	50	5	1.30 ⁴
FVP1	3	50	47	5.64 ⁴
FVP1	4	50	40	5.96 ⁴
FVP2	1	50	11	1.73 ⁵
FVP2	2	50	26	3.23 ⁵
FVP2	3	50	45	7.05 ⁵
FVP2	4	50	43	5.87 ⁵
Reference	1	50	58	16.67
Reference	2	50	57	17.06
Reference	3	50	51	15.44
Reference	4	50	55	18.29

- 1 Increase in earthworm numbers due to reproduction and the growth of small worms during test.
- 2 Compositated for chemical analysis "OHI1 Composite."
- 3 Compositated for chemical analysis "OHO Composite."
- 4 Compositated for chemical analysis "FVP1 Composite."
- 5 Compositated for chemical analysis "FVP2 Composite."

necessities for growth and continued maintenance, in the absence of other related biotic communities, when tested as an upland soil. This is certainly typical of any marine sediment, whether considered contaminated or not, and will require management if the sediment is used to create a freshwater, upland ecosystem.

Earthworm toxicity has been demonstrated to parallel mammalian toxicity for many hazardous substances (Callahan 1991). In addition, earthworms are also excellent indicators of potential bioaccumulation of contaminants by all classes of animals. Since the earthworm seldom metabolizes the compound taken

Table VII-2
Heavy Metal Concentration in Bioassay Earthworms
(Concentration in $\mu\text{g/g}$ Dry Weight)

Substrate	As	Cr	Cu	Ni	Pb ¹	Se	Zn	Cd ¹	Hg ¹
OH0 Composite	11.51+	33.1+	17.2-	8.97+	2.11+	3.74+	93.8-	3.930	0.081+
OH1 Composite	11.83+	79.4+	19.2-	11.57+	1.64+	3.34	107.1-	3.580	0.078+
FVP1 Composite	6.07+	124.3+	168.2+	12.2+	22.8+	4.66+	166.7	7.260	0.765+
FVP2 Composite	8.27+	83.1+	190.5+	7.46+	13.5+	4.96+	150-	5.050	0.445
Reference Rep 1	4.51	<3.2	22.7	1.85	0.872	3.13	175	5.390	0.044
Reference Rep 2	4.58	<3.6	24.8	2.3	0.842	3.07	177.1	5.120	0.044
Reference Rep 3	4.91	<3.7	23.5	1.08	0.226	3.41	162.9	1.900	0.011
Reference Rep 4	4.54	3.8	24.1	2.28	0.849	3.39	183.7	6.330	0.041
Reference Mean	4.64	3.6	23.8	1.88	0.70	3.25	174.7	4.69	0.035
Reference Standard Error	0.09	0.13	0.45	0.29	0.16	0.09	4.34	0.96	0.008

¹ ICP\MS Technique

+ Value is statistically greater than the Reference Mean using a one tailed t-test at $\alpha=0.01$.

- Value is statistically less than the Reference Mean using a one tailed t-test at $\alpha=0.01$.

Table VII-3
PCB Concentration in Bioassay Earthworms
(Concentration in $\mu\text{g/kg}$ Wet Weight)

<u>Substrate</u>	<u>Aroclor 1242</u>	<u>Aroclor 1248</u>	<u>Aroclor 1254</u>	<u>Aroclor 1260</u>
OHI1 Composite	<17.471	<17.471	320.121	<17.471
OHO Composite	<8.901	<8.901	104.985	<8.901
FVP1 Composite	<10.915	<10.915	2026.302	<10.915
FVP2 Composite	<28.734	<28.734	3289.12	<28.734
Reference Rep 3	<8.559	<8.559	<8.559	<8.559

Table VII-4
PAH Concentration in Bioassay Earthworms
(Concentration in $\mu\text{g/kg}$ Wet Weight)

<u>PAH</u>	<u>OHO COMP</u>	<u>OHI1 COMP</u>	<u>FVP 1 COMP</u>	<u>FVP 2 COMP</u>	<u>REF REP 3</u>
Acenapththene	<1.46	<3.74	<3.33	<8.76	<1.33
Acenapththylene	<5.03	<0.87	9.23	<6.33	<4.83
Anthracene	2.39	5.47	8.14	<4.14	<2.14
Benzo (a) anthracene	11.95	27.11	24.59	19.06	<0.47
Benzo (b) fluoranthene	33.12	117.57	215.92	197.25	<0.93
Benzo (k) fluoranthene	25.08	95.5	139.62	90.2	<0.78
Benzo (a) Pyrene	M	M	M	M	<3.18
Benzo (g,h,i) Perylene	<5.38	10.59	<6.6	<12.67	<5.17
Chrysene	22.52	57.42	183.54	132.87	<0.88
Dibenzo (a,h) anthracene	<2.7	<5.29	<1.78	<8.71	<2.59
Fluoranthene	12.26	38.07	32.48	25.25	<0.48
Fluorene	<1.04	<3.23	<2.04	<3.19	<1.18
Indeno-(1,2,3-c,d) Pyrene	<3.97	<7.78	<4.86	<12.8	<3.81
Naphthalene	B	B	B	B	B
Phenanthrene	4.75	16.86	24.25	19.66	3.2
Pyrene	86.76	378.65	38.95	34.29	<0.57

M - matrix interference.

B - compound present in blanks.

up from its environment, the compounds are found in the earthworm as the parent compounds and not the many metabolites typical of higher systems (Reddy et al. 1991). This permits a more accurate evaluation of the extent of

Table VII-5
Pesticide Concentrations in Bioassay Earthworms
(Concentrations in $\mu\text{g/kg}$ Wet Weight)

<u>Pesticide</u>	<u>Substrate</u>				<u>Ref. Rep 3</u>
	<u>OHI1 Comp.</u>	<u>OHO Comp.</u>	<u>FVP1 Comp.</u>	<u>FVP2 Comp.</u>	
a-BHC	<0.609	<0.311	<0.381	<1.002	0.304
b-BHC	<0.609	<0.311	<0.381	<1.002	<0.299
d-BHC	5.939	<0.311	<0.381	<1.002	<0.299
Lindane	6.514	<0.311	4.358	<1.002	<0.299
Heptachlor	<2.051	<0.635	14.403	<2.051	<0.611
Aldrin	1.225	6.65	6.796	<0.979	0.635
Heptachlorepoxyde	1.215	0.945	<0.427	<1.123	<0.335
Endosulfan sulfate	11.899	9.327	<1.092	28.155	<0.856
a-Endosulfan	2.634	<1.35	11.696	19.831	0.954
Dieldrin	<4.716	12.86	17.959	<9.948	<3.114
Endrin	<5.996	5.95	<3.746	<9.861	<2.937
b-Endosulfan	2.298	6.244	<1.092	13.6	<0.856
Endrin aldehyde	<1.747	<0.89	<1.092	<2.873	<0.856
Toxaphene	<17.471	<8.901	<10.915	<28.734	<8.559
pp DDE	30.301	21.859	18.193	43.678	0.562
pp DDD	29.311	25.619	9.29	60.587	<0.201
pp DDT	2.613	1.22	9.278	2.108	<0.628
Chlordane	<17.471	<8.901	<10.915	<28.734	<8.559

contaminant uptake. The individual classes of compounds are discussed in the following paragraphs.

Metal accumulation by test earthworms is summarized in Table VII-2. All metals were relatively low in earthworms in the Manure Reference medium. Tissue arsenic, chromium, nickel and lead statistically higher in the earthworms exposed to both Oakland Harbor sediments and FVP dredged material in comparison to those in the Manure Reference. Arsenic concentrations in earthworm tissues appeared to be slightly above the Australian FDA-like action level of $10 \mu\text{g/g}$ for shellfish and fish. This indicates a potential for soil invertebrates to accumulate arsenic to concentrations that would be of concern

to the Australians and perhaps should be of concern to Americans. Earthworm tissue content of cadmium was not statistically different across the test substrates. Although there is very little data on the effects of elevated nickel in soil invertebrates, management may be required. There are no advisory or regulatory guidelines for nickel levels that can be used to place these data in perspective. However, the accumulation of nickel did not exceed an order of magnitude over the manure reference values, and therefore should be of a low concern. Earthworm zinc concentrations were the lowest in the Oakland Harbor sediments when compared to the Manure Reference or the FVP dredged material containing 1,370 mg/kg Zn. In addition, plants grown in the Oakland Harbor sediment contained reduced tissue zinc contents which might indicate a possible zinc deficiency. Chromium and to a lesser extent, lead concentrations were also elevated in the bioassay earthworms exposed to the Oakland Harbor sediments in comparison to the Manure Reference. Earthworm tissue levels of chromium from the Oakland Inner Harbor sediment (OH11) approached those from earthworms exposed to the FVP dredged material, which contains approximately 1,403 mg/kg chromium. In the wetland mesocosm testing of Oakland Harbor sediments (Lee et al. 1993), elevated chromium and lead concentrations were observed in snails collected from an undisturbed area by a contractor and supplied for bioassay testing. Consequently, there may be an elevated ambient level of chromium and lead in the environment of San Francisco Bay.

The results of the bioassessment for PCBs are shown in Table VII-3. Only one PCB mixture, Aroclor 1254, was detected in Oakland Inner and Outer Harbor sediments and accumulated above detection limits by earthworms exposed to those substrates. Aroclor 1254 concentrations are well below those of the earthworms exposed to the contaminated FVP dredged material reference that contained 6.8 mg/kg Aroclor 1254.

Anthracene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)-fluoranthene, fluoranthene, chrysene, phenanthrene, and pyrene were found above detection limits in the tissues of earthworms exposed to both Oakland Harbor sediments (OHO and OH11, Table VII-4). Tissue concentrations of these PAHs appeared to be slightly higher in earthworms exposed to Oakland Inner Harbor sediment (OH11) than those exposed to Oakland Outer Harbor sediment (OHO). In addition, earthworms exposed to Oakland Inner Harbor sediment accumulated benzo(g,h,i)perylene. Earthworm levels of many PAHs exposed to OH11 were in the range of those animals exposed to FVP dredged material

references, which contained sediment concentrations of the sum of PAHs of 142 mg/kg (individual PAHs ranged up to 9.8 mg/kg on a dry weight basis).

The exposure of earthworms to the Oakland Harbor test sediments resulted in accumulation of numerous pesticides to levels above detection limits and in the range of tissue concentrations produced by the contaminated FVP dredged material references (Table VII-5). Dieldrin and endrin were detected in earthworms exposed only to the Oakland Outer Harbor sediment. However, the bioassay earthworms indicated that aldrin, heptachlorepoxyde, endosulfan sulfate, b-endosulfan, $PPDDT$, $PPDDE$, and $PPDDD$ were accumulated from both Oakland Harbor sediments. Lindane, d-BHC, and a-endosulfan were also accumulated from Oakland Inner Harbor sediment (OH11) by the bioassay earthworms. None of the observed earthworm tissue levels resulting from exposure to the Oakland Harbor sediments was of significance when put in perspective to existing FDA action levels for shellfish and fish. The bioassay did indicate that pesticides, otherwise undetected, are present and are bioavailable to soil invertebrates, but result in relatively low levels in tissues.

Animal Impacts and Controls

A wide variety of animals may colonize the dredged material following disposal. Prior to the establishment of vegetation, the site will most likely attract various gulls and terns that may even nest on the site. Species such as these do not feed on site and can only be impacted by their contact with the dredged material. Large colonies of shorebirds may be difficult to manage and may result in the occurrence of common diseases (Simmers et al. 1990). With the establishment of vegetation, the disposal site will be colonized by earthworms and other soil invertebrates that predominantly live and feed in the leaf litter produced by the plants. There is a potential for soil invertebrates to bioaccumulate arsenic to concentrations equal to or above the Australian FDA-like action level of 10 $\mu\text{g/g}$ for shellfish and fish. Foodwebs may become contaminated with arsenic at the upland disposal site. It is noteworthy that snails collected in the San Francisco Bay area contained 17 $\mu\text{g/g}$ arsenic as a background tissue concentration. These data suggest a relatively high ambient arsenic concentration in the environments around San Francisco Bay. There is some potential for metals such as Cd to move through the herbivore food chain but not into insectivores (Stafford et al. 1991). A monitoring plan should be employed to evaluate the mobility of metals such as

arsenic, nickel and cadmium in the ecosystems that are allowed to become established on an Oakland Harbor sediment upland disposal facility in both the short and long term.

There is no information concerning the potential movement of butyltins from soil invertebrates into the terrestrial food web. Insectivores and small herbivores should be sampled for butyltin content as the site is naturally colonized, or the disposal area should be planted with vegetation that deters colonization by birds and mammals.

PCB movement from soil invertebrates to higher organisms such as insectivorous birds does not appear to pose any problem (Stafford et al. 1991). However, there are no data concerning the movement of PCBs in the herbivore food web. Tissue PCB concentrations in earthworms exposed to Oakland Harbor sediments were an order of magnitude below FDA action levels for shellfish and fish. Earthworms exposed to FVP dredged material contained tissue PCB concentrations equal to or above the FDA action level of 2,000 $\mu\text{g}/\text{kg}$ and would be of concern.

Levels of pesticides in bioassay earthworms were relatively low when FDA levels are considered. Levels of PAHs in bioassay earthworm tissues appear to suggest the need for management practices to isolate these compounds from food webs that may become established on the dredged material.

PART VIII: CONCLUSIONS AND RECOMMENDATIONS

Metal concentrations in Oakland Inner and Oakland Outer Harbor sediments were compared to the Twitchell Island soil concentrations from a previous evaluation. Most of these metals are not unusually elevated but chromium and lead in both Oakland Inner and Outer Harbor sediments appeared to be higher than the chromium and lead at Twitchell Island and in the levee soils collected from Twitchell Island.

Butyltin concentrations in Oakland Harbor sediments appeared to be elevated in comparison to the Twitchell Island soils but are much less than the concentrations of butyltins found in the turning basin sediment of Oakland Inner Harbor (Lee et al. 1992).

Oakland Inner and Oakland Outer Harbor sediments appear to contain lower concentrations of PAHs than previous tested Twitchell soils. Pesticide concentrations in Oakland Harbor sediments are low parts per billion range.

Effluent test results indicated that, with the exception of copper and tributyltin, the dissolved concentrations of all contaminants discharged as effluent will meet all assumed water quality criteria or standards prior to any mixing. The concentrations of dissolved contaminants exceeding assumed criteria or standards will require a dilution of up to 2 for Oakland Inner Harbor sediment and 21 for Oakland Outer Harbor sediment in the mixing zone to meet the assumed criteria or standards. This degree of mixing can generally be achieved within a short distance of the effluent discharge.

The salinity of the effluent could potentially cause some adverse environmental impacts. A dilution of approximately 10 to 1 would reduce the salinity to less than 2 ppt and would minimize any impacts due to salinity. Bioassay tests indicated no toxicity associated with exposure of sensitive test organisms to the Oakland Harbor sediment modified elutriates.

Contaminants in surface runoff from the Inner and Outer Oakland Harbor sediments were mostly bound to the sediment particulates. Significant quantities of arsenic, cadmium, chromium, copper, zinc, and tributyltin could be eroded from an upland disposal site during the wet, unoxidized stage if the suspended solids were not removed from the runoff.

Potential migration of contaminants in surface runoff water during the wet, unoxidized period of upland disposal would be mostly associated with erosion of particulates. Management of the upland disposal site to remove particulates from surface runoff, would remove 90 to 99 percent of all

contaminants in surface runoff. Only soluble copper concentrations in runoff from the Oakland Inner Harbor sediment exceeded the assumed EPA Acute water quality criteria for marine environments and soluble arsenic exceeded the assumed Receiving Water Quality Limitation standards. Soluble arsenic concentrations exceeded the assumed Receiving Water Quality Limitation standards in runoff from the Oakland Outer Harbor sediment but copper did not exceed the assumed EPA criteria. Consideration of a mixing zone at the discharge point from the upland disposal site and/or further treatment may be required for those soluble contaminants. A mixing zone ratio of about 10 to 1, receiving water to runoff water, would be required to dilute arsenic concentrations in surface runoff water to the assumed Receiving Water Quality Limitation standards. A ratio of 3 to 1 would be required to dilute copper concentrations to the assumed EPA water quality criteria for marine environments.

Potential contaminant migration in surface runoff from dry, oxidized sediments should occur only from copper, chromium, zinc, cadmium and arsenic bound to the suspended solids. Only soluble arsenic exceeded the assumed Receiving Water Quality Limitation standard in both sediments. Consideration of a mixing zone or removal of the suspended solids should eliminate the need for further restrictions particularly with regard to treatment of soluble contaminants. Establishment of vegetation either by natural succession or by planting would further reduce contaminant concentrations in surface runoff. A mixing zone of less than 10 to 1 would be required to dilute unfiltered contaminant concentrations to less than or equal to the strictest criteria, and a mixing zone of about 2 to 1 would be required for soluble arsenic.

Exposure of sensitive test animals to Oakland sediment runoff waters showed little potential for aquatic toxicity. Mean survival was usually greater than 90 percent for all treatments, even for animals exposed to 100 percent runoff water.

The oxidation of Oakland Harbor sediment resulted in increased leaching of metals compared to anaerobic sediment. The increase in metals leaching was not extremely high, but leaching under aerobic conditions indicates that leachate metals concentrations will be higher if dredged material in an upland facility is drained to the extent that oxidizing conditions exist throughout the dredged material. From a management perspective, these results indicate that metals mobility can be reduced by maintaining anaerobic conditions.

Maximum Contaminant Levels (MCLs) established under the Safe Drinking Water Act were not exceeded by any of the leachate data. Assumed effluent or

Discharge Limitation standards for copper and tributyltin were exceeded in at least one test for Oakland Inner and Outer Harbor sediments. Effluent Limitation standards for cadmium and zinc also were exceeded for the Oakland Inner Harbor sediment. Assumed receiving Water Quality Limitation standards were exceeded for all contaminants with the exception of chromium for both Oakland Harbor sediments and zinc in the Oakland Inner Harbor sediment.

The plant bioassay test indicated that plant growth on either Oakland Inner or Outer Harbor sediment was poor. Tissue contents of cadmium, lead, and selenium appeared to be elevated in plants grown in Oakland Outer Harbor sediment and should be of concern. Consideration of restrictions and controls is warranted for plants colonizing Oakland Outer Harbor sediments placed in an upland disposal environment.

Both Oakland Harbor sediments were not toxic to earthworms after sediment salinity was reduced by washing (leaching). While earthworms survived in both Oakland Harbor sediments, they showed reduced weights compared to those in the manure reference. In order to obtain chemical analysis of earthworm tissues, composite samples of replicates were made. There is a potential for soil invertebrates to bioaccumulate arsenic to concentrations equal to or above the Australian FDA-like action level of 10 $\mu\text{g/g}$ for shellfish and fish. Foodwebs may become contaminated with arsenic at the upland disposal site. It is noteworthy that snails collected in the San Francisco Bay area contained 17 $\mu\text{g/g}$ arsenic as a background tissue concentration. These data suggest a relatively high ambient arsenic concentration in the environments around San Francisco Bay. There is some potential for metals such as Cd to move through the herbivore food chain, but not into insectivores (Stafford et al. 1991). A monitoring plan should be employed to evaluate the mobility of metals such as arsenic, nickel and cadmium in the ecosystems that are allowed to become established on an Oakland Harbor sediment upland disposal facility in both the short and long term.

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PCB movement from soil invertebrates to higher organisms, such as insectivorous birds, does not appear to pose any problem (Stafford et al. 1991). However, there are no data concerning the movement of PCBs in the herbivore

food web. Tissue PCB concentrations in earthworms exposed to Oakland Harbor sediments were an order of magnitude below FDA action levels for shellfish and fish. Earthworms exposed to FVP dredged material contained tissue PCB concentrations equal to or above the FDA action level of 2,000 $\mu\text{g}/\text{kg}$ and would be of concern.

Levels of pesticides in bioassay earthworms were relatively low when FDA action levels are considered. Levels of PAHs in bioassay earthworm tissues appear to suggest the need for management practices to isolate these compounds from food webs that may become established on the dredged material.

REFERENCES

American Public Health Association. 1976. Standard Methods for the Examination of Water and Wastewater, 14th ed., Washington, DC.

Barr, A. J., Goodnight, J. H., Sall, J. P., and Helwig, J. T. 1976. "A User's Guide to SAS 76," SAS Institute, Inc., Raleigh, NC.

Bejin, M. S. 1985. "A Program Package of Analytical Models for Solute Transport in Ground Water, SOLUTE," International Ground Water Modeling Center, Holcomb Research Institute, Butler University, Indianapolis, IN.

Brandon, D. L., Lee, C. R., Simmers, J. W., Skogerboe, J. G., and Wilhelm, G. S. 1991. "Interim Report: Long-Term Evaluation of Plants and Animals Colonizing Contaminated Estuarine Dredged Material Placed in Both Upland and Wetland Environments," Miscellaneous Paper D-91-5, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Brannon, J. M., Plumb, R. H., Jr., and Smith, I. 1978. "Long-Term Release of Contaminants From Dredged Material," U.S. Army Engineer Waterways Experiment Station Technical Report D-78-49, Vicksburg, MS.

Brannon, J. M., Myers, T. E., and Price, C. B. 1990. "Factors Affecting the Behavior of Metals in Leachate," Environmental Effects of Dredging Technical Note EEDP-02-13, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Brannon, J. M., Myers, T. E., Gunnison, D., and Price, C. B. 1991. "Nonconstant Polychlorinated Biphenyl partitioning in New Bedford Harbor Sediment during Sequential Batch Leaching," Environmental Science and Technology, Vol 25, No. 6, pp 1082-1087.

California Regional Water Quality Control Board. 1989. "Delta Levee Disposal of Port of Oakland Dredge Spoils Waste Discharge Requirements," Staff Report, Sacramento, CA.

Callahan, C. A. 1991. "Bioassay of Contaminated Sites," Proceedings of the International Workshop on Earthworm Ecotoxicology (in press), Sheffield, UK.

CEC (Commission of the European Communities). 1984. "Methods for the Determination of Ecotoxicity-Level 1, Earthworms-Artificial Soil," Directive 79/831, Annex V, Part C, Commission of the European Communities, DG XI/128/82, Rev. 5.

Chaney, R. L. 1983. "Potential Effects of Waste Constituents on the Food Chain in Land Treatment of Hazardous Wastes," Noyes Data Corporation, Park Ridge, NJ, pp 152-240.

Day, P. R. 1956. Report of the Committee on Physical Analyses (1954-1955), Soil Sci. Soc. Am. Proc., Vol 20, pp 167-169.

Edwards, N. T. 1983. "Polycyclic Aromatic Hydrocarbons (PAH's) in Terrestrial Environment - A Review," Journal of Environmental Quality, Vol 12, No. 4, pp 427-441.

Environmental Laboratory. 1987a. "Disposal Alternatives for PCB-Contaminated Sediments from Indiana Harbor, Indiana; Vol I: Main Report," Miscellaneous Paper EL-87-9, U.S. Army Engineer Waterways Experiment station, Vicksburg, MS.

Environmental Laboratory. 1987b. "Disposal Alternatives for PCB-Contaminated Sediments from Indiana Harbor, Indiana; Vol II: Appendixes A-J," Miscellaneous Paper EL-87-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. Environmental Protection Agency/Corps of Engineers. 1977 (Jul). "Implementation Manual for Section 103 of Public Law 92-532 (Marine Protection, Research, and Sanctuaries Act of 1972)," U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

European Community. 1974. "Tot Vastelling van de Maximale Gehalten aan Ongewenste Stoffen en Produkten in Diervoeders," Publ. blad EEG, Vol 17, No. L38, pp 31-36.

Folsom, B. L., Jr., Davis, B. E., and Houghton, N. J. 1988. "Heavy Metal Uptake by Agronomic Crops and *Cyperus esculentus* Grown on Oxidized and Reduced Soils Contaminated with Metal-Mining Wastes," Environmental Effects of Dredging Technical Note EEDP-02-06, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Folsom, B. L., Jr., and Houck, M. H. 1990. "A Computerized Procedure for Predicting Plant Uptake of Heavy Metals from Contaminated Freshwater Dredged Material," Environmental Effects of Dredging Technical Note EEDP-04-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Folsom, B. L., Jr., Lee, C. R., and Bates, D. J. 1981. "Influence of Disposal Environment on Availability and Plant Uptake of Heavy Metals in Dredged Material," Technical Report EL-81-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Folsom, B. L., Jr., Pennington, J. C., Teeter, C. L., Barton, M. R., and Bright, J. A. 1988. "Effects of Soil pH and Treatment Level on Persistence and Plant Uptake of 2,4,6-Trinitrotoluene," Technical Report EL-88-22, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Folsom, B. L., Jr., Skogerboe, J. G., Palermo, M. R., Simmers, J. W., Pranger, S. A., and Shafer, R. A. 1988. "Synthesis of the Results of the Field Verification Program Upland Disposal Alternative," Technical Report D-88-7, U.S. Army Engineer Waterways Experiment Station, Environmental Laboratory, Vicksburg, MS.

Francingues, N. R., Palermo, M. R., Lee, C. R., and Peddicord, R. K. 1985. "Management Strategy for Disposal of Dredged Material: Test Protocols and Contaminant Control Measures," Miscellaneous Paper D-85-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Francois, R., and Weber, J. H. 1988. "Speciation of Methyltin and Butyltin Compounds in Eelgrass (*Zostera marina* L.) Leaf Tissue from the Great Bay Estuary (NH)," Marine Chemistry, Vol 25, pp 279-289.

Gal, J. Y., and Bouche, M. B. 1988. "Correlation of Lethal Concentrations of Heavy Metals with Tissue Levels of Earthworms," Technical Report, Laboratoire

de Zooecologie du Sol and Laboratoire de Chime Analytique, University of Montpellier, France.

Harding Lawson Associates. 1989. "Final Water Quality Impact Evaluation, Land Disposal of Dredged Sediments from the Oakland Inner Harbor, Alameda County, California," report prepared for Port of Oakland, Oakland, CA.

Hill, D. O., Myers, T. E., and Brannon, J. M. 1988. "Development and Application of Techniques for Predicting Leachate Quality in Confined Disposal Facilities; Part I: Background and Theory," Miscellaneous Paper EL-88-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Holmgren, G. G. S., Meyer, M. W., Daniels, R. B., Chaney, R. L., and Kubota, J. 1993. "Cadmium, Lead, Zinc, Copper, and Nickel in Agricultural Soils of the United States," Journal of Environmental Quality 22: 335-348.

Kay, S. H., Scholten, M. C. Th., and Bowmer, C. T. 1988. "Mobility of Soil Contaminants in an Ecosystem of Trees Growing on Dredged Material - The Broekpolder (Rotterdam, The Netherlands," Technical Report R88/488, Technology for Society Division (MT) of Netherlands Organization for Applied Scientific Research (TNO), Delft, NL.

Klute, A. 1965. "Water Capacity," Methods of Soil Analysis, C. A. Black, ed., Monograph No. 9, American Society of Agronomy, Madison, WI, pp 273-278.

Krivolutski, D., Turganinova, V., and Mikhaltsova, Z. 1982. "Earthworms as Bioindicators of Radioactive Soil Pollution," Pedobiologia, Vol 23, pp 263-265.

Lee, C. R., et al. 1978. "Prediction of Heavy Metal Uptake by Marsh Plants Based on Chemical Extraction of Heavy Metals from Dredged Material," Technical Report D-78-6, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lee, C. R., Folsom, B. L., Jr., and Bates, D. J. 1983. "Prediction of Plant Uptake of Toxic Metals Using a Modified DTPA Soil Extractant," The Science of the Total Environment, No. 28, pp 191-202.

Lee, C. R., Folsom, B. L., Jr., and Engler, R. M. 1982. "Availability and Uptake of Heavy Metals from Contaminated Dredged Material Placed in Flooded and Upland Disposal Environments," Environment International, No. 7, pp 65-71.

Lee, C. R., and Skogerboe, J. G. 1984. "Restoration of Pyritic Soils and the Quantification of Erosion Control," Miscellaneous Paper EL-84-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lee, C. R., et al. 1991. "General Decisionmaking Framework for Management of Dredged Material; Example Application to Commencement Bay, Washington," Miscellaneous Paper D-91-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lee, C. R., et al. 1992. "Evaluation of Upland Disposal of Oakland Harbor, California, Sediment; Volume I: Turning Basin Sediments," Miscellaneous Paper EL-92-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Louisiana Water Resources Research Institute. 1990. "Synopsis of Research Needs Workshop: Development of Leach Tests for Contaminated Dredged Material," Miscellaneous Paper D-90-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

McLane, M. R., Stickel, L., and Newsom, J. 1971. "Organochlorine Pesticide Residues in Woodcock, Soils, and Earthworms in Louisiana," Pesticides Monitoring Journal, Vol 3, pp 248-250.

Marquenie, J. M., Simmers, J. W., and Kay, S. H. 1987. "Bioaccumulation of Metals and Organic Contaminants at the Times Beach Confined Disposal Site, Buffalo, New York," Miscellaneous Paper EL-87-6, U.S. Army Engineer Waterways Experiment Station, Environmental Laboratory, Vicksburg, MS.

Morin, J., Goldberg, D., and Seginer, I. 1967. "A Rainfall Simulator with a Rotating Disk," Transactions of the American Society of Agricultural Engineers, Vol 10, No. 1, pp 74-79.

Morin, J., Cluff, D. B., and Powers, W. R. 1970. "Realistic Rainfall Simulation for Field Investigation," presented at the 51st Meeting of American Geophysical Union, Washington, DC.

Myers, T. E., and Brannon, J. M. 1988. "New Bedford Harbor Superfund Project, Acushnet River Estuary Engineering Feasibility Study of Dredging and Dredged Material Disposal Alternatives; Report 5, Evaluation of Leachate Quality," Technical Report EL-88-15, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Myers, T. E., Brannon, J. M., and Price, C. B. 1992. "Recent Developments in Leachate Testing and Evaluation," Miscellaneous Paper D-92-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Nielson, K. K., and Sanders, R. W. 1983. "Multielement Analysis of Unweighed Biological and Geological Samples Using Backscatter and Fundamental Parameters," Adv. X-ray Anal., Vol 26, pp 385-390.

Ogata, A., and Banks, R. B. 1961. "A Solution of the Differential Equation of Longitudinal Dispersion in Porous Media," U.S. Geological Survey Professional Paper 411-A, Reston, VA.

Palermo, M. R. 1985. "Interim Guidance for Predicting the Quality of Effluent Discharged from Dredged Material Disposal Areas," Environmental Effects of Dredging Technical Notes EEDP-04-1 through 4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Palermo, M. R. 1986. "Development of a Modified Elutriate Test for Estimating the Quality of Effluent from Confined Dredged Material Disposal Areas," Technical Report D-86-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Palermo, M. R., et al. 1989. "Evaluation of Dredged Material Disposal Alternatives for U.S. Navy Homeport at Everett, Washington," Technical Report EL-89-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Patrick, W. H., Jr. 1958. "Modification of Method of Particle Size Analysis," Soil Sci. Soc. Am. Proc., Vol 22, pp 366-267.

Patrick, W. H., Jr. 1990. "A Field and Laboratory Investigation of Toxic Heavy Metal Release from Oakland Inner Harbor Sediments," report submitted to Port of Oakland, Oakland, CA.

Peddicord, R. K., et al. 1986. "General Decisionmaking Framework for Management of Dredged Material - Example Application to Commencement Bay, Washington," Draft Miscellaneous Paper, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Reddy, T. V., Chang, L. W., and Daniel, F. B. 1991. "Absorption, Distribution and Metabolism of Polycyclic Aromatic Hydrocarbons (PAH) in the Earthworm," Abstract P268, p 205, 12th Annual Meeting, Society of Environmental Toxicology and Chemistry, Seattle, WA.

Rhett, R. G., Adema, D. M. M., Roza, P., and Henzen, R. 1989. "Rate and Effects of PCB Accumulation on Eisenia foetida," Technical Report R89/339, Technology for Society Division (MT) of Netherlands Organization for Applied Scientific Research (TNO), Delft, NL.

Rhoades, J. D. 1982. "Soluble Salts," Methods of Soil Analysis, C. A. Black, ed., Monograph No. 9., American Society of Agronomy, Madison, WI, pp 167-179.

Rice, C. D., Espourteille, F. A., and Huggett, R. J. 1987. "Analysis of Tributyltin in Estuarine Sediments and Oyster Tissue, Crassostrea virginica," Applied Organometal Chemistry, Vol 1, pp 541-544.

Schroeder, P. R., Peyton, R. L., McEnroe, B. M., and Sjostron, J. W. 1988. "The Hydrologic Evaluation of Landfill Performance (HELP) Model; Volume III: User's Guide for Version 2," Draft Instruction Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Schroeder, P. R., and Palermo, M. R. 1990. "The Automated Dredging and Disposal Alternatives Management System (ADDAMS)," Environmental Effects of Dredging Technical Note EEDP-06-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Seligman, P. F., Valkirs, A. O., and Lee, R. F. 1986. "Degradation of Tributyltin in San Diego Bay, California, Waters," Environmental Science and Technology, Vol 20, pp 1229-1237.

Short, J. W., and Sharp, J. L. 1989. "Tributyltin in Bay Mussels (Mytilus edulis) of the Pacific Coast of the United States," Environmental Science and Technology, Vol 23, pp 740-743.

Simmers, J. W., Apfelbaum, S. A., and Bryniarski, L. F. 1990. "Assessment of Avian Botulism Control Pilot Project at Dike 14 Confined Dredged Material Disposal Facility, Cleveland, Ohio," Miscellaneous Paper EL-90-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Simmers, J. W., Lee, C. R., Tatem, H. E., Price, R. A., Brandon, D. L., and Miner, S. P. 1993. "Evaluation of Wetland Creation with Oakland Harbor, California, Sediment," Miscellaneous Paper (in review), U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Skogerboe, John G., et al. 1987. "Prediction of Surface Runoff Water Quality from Black Rock Harbor Dredged Material Placed in an Upland Disposal Site," Miscellaneous Paper D-87-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Sokal, R. R., and Rohlf, F. J. 1981. Biometry. The Principles and Practice of Statistics in Biological Research, 2nd ed., W. H. Freeman and Company, San Francisco, CA.

Stafford, E. A., Simmers, J. W., Rhett, R. G., and Brown, C. P. 1991. "Interim Report: Collation and Interpretation of Data for Times Beach Confined Disposal Facility Buffalo, New York, Facility, Buffalo, New York," Miscellaneous Paper D-91-17, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Tatem, H. E. 1990. "Determination of the Chemical Suitability of a Dredged Material Containment Area for Aquaculture," Technical Report EL-90-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Unger, M. A., MacIntyre, W. G., Greaves, J., and Huggett, R. J. 1986. "GC Determination of Butyltins in Natural Waters by Flame Photometric Detection of Hexyl Derivatives with Mass Spectrometric Confirmation," Chemosphere, Vol 15, No. 4, pp 461-470.

U.S. Army Corps of Engineers. 1970. "Laboratory Soils Testing," Engineer Manual 1110-2-1906, Washington, DC.

_____. 1987. "Confined Disposal of Dredged Material," Engineer Manual 1110-2-5027, Washington, DC.

USEPA. 1979. "Criteria for Classification of Solid Waste Disposal Facilities and Practices," Federal Register, Vol 44, No. 179, pp 53, 438-453, 464.

_____. 1984. "EPA Par VIII 40 CFR, Part 136, Methods 608 and 625," Washington, DC.

_____. 1986. "Test Methods for Evaluating Solid Wastes, SW-846 Methods 8080 and 8270," 3rd ed., Office of Solid Waste and Emergency Response, Washington, DC.

USACE/EPA. 1992. "Evaluating Environmental Effects of Dredged Material Management Alternatives - A Technical Framework," EPA842-B-92-008, U.S. Environmental Protection Agency and U.S. Army Corps of Engineers, Washington, DC.

USEPA. 1987. "Update #2 to Quality Criteria for Water 1986," Office of Water Regulations and Standards Criteria and Standards Division, Washington, DC.

van Driel, W., Smilde, K. W., and van Luit, B. 1985. "Comparison of the Heavy-Metal Uptake of Cyperus esculentus and of Agronomic Plants Grown on Contaminated Dutch Sediments," Miscellaneous Paper D-83-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Ward, J. A., Word, J. Q., Pinza, M. R., Mayhew, H. L., Barrows, E. S., and Lefkovitz, L. F. 1992a. "Ecological Evaluation of Proposed Discharge of Dredged Material from Oakland Harbor into Ocean Waters (Phase IIIA of -42-Foot Project); Volume 1: Analyses and Discussion," PNL-83-2, Vol 1, Battelle/Marine Science Laboratory, Sequim, WA.

Ward, J. A., Word, J. Q., Pinza, M. R., Mayhew, H. L., Barrows, E. S., and Lefkovitz, L. F. 1992b. "Ecological Evaluation of Proposed Discharge of Dredged Material from Oakland Harbor into Ocean Waters (Phase IIIA of -42-Foot Project); Volume 2: Appendixes," PNL-83-2, Vol 2, Battelle/Marine Science Laboratory, Sequim, WA.

Westerdahl, H. E., and Skogerboe, J. G. 1982. "Realistic Rainfall and Watershed Response Simulations for Assessing Water Quality Impacts of Land Use Management," Modeling Components of Hydrologic Cycle, International Symposium on Rainfall-Runoff Modeling, Mississippi State University, Mississippi State, MS, pp 87-104.

Winer, B. J. 1971. Statistical Principles in Experimental Design, McGraw-Hill, New York.

World Health Organization. 1972. "Evaluation of Certain Food Additives, Mercury, Lead, and Cadmium," Technical Report Series 505.

APPENDIX A: SEDIMENT COLLECTION AND CHEMICAL CHARACTERIZATION

**Field Sampling: Battelle, Pacific
Northwest Laboratories
Sediment Chemical Characterization
Sediment Physical Characterization
Oakland Inner Harbor
Oakland Outer Harbor**

2.0 MATERIALS AND METHODS

2.1 SEDIMENT COLLECTION

The MSL collected four types of sediment samples from 35 stations (Figures 2.1 through 2.4) during June 1990 to achieve the objectives of the Phase III A Project. Because of unacceptably low control survival for the polychaetes in the initial *M. nasuta*/*N. caecoides* 10-day (86% survival) and 28-day (59% survival) tests, the tests were rerun. During the September 1990 sampling efforts, sediments were collected for Oakland Harbor Phase III 38-Foot and Oakland Harbor Phase III A retest programs. The sediments were retested using *M. nasuta* and *N. caecoides* at the following stations: I-C3, I-C5, I-C7 through I-C12, I-C14 through I-C18, I-S1, I-T1, and I-T3. The control and reference sediments used for the *M. nasuta*/*N. caecoides* retest were from the same locations as those collected during the Phase III A Project. The Phase III 38-Foot Program was run concurrently with the Phase III A retest. Phase III 38-Foot data are provided in Ward et al. 1992. The results of both the Phase III A and Phase III A retest programs are presented in the following sections. Table 2.1 lists the code identification of the samples collected, the sediment treatments prepared, and the analyses performed on each sediment treatment.

2.1.1 Oakland Harbor Sediment Sampling Methods

Two types of vibratory-hammer core samplers, a 12-in.-diameter split core and a 4-in.-diameter core (Figure 2.5), were used to collect sediment samples from Oakland Inner and Outer Harbors for the Phase III A Project. Both coring devices were designed by MSL and Manson Construction and Engineering Company of Richmond, California, to sample highly compacted sediments that could not be penetrated by conventional coring devices.

Manson also supplied the derrick barge *Hagar*, a push boat, support equipment, and vessel and coring crews for the Phase III A sampling program. The *Hagar* provided a 150-ft x 60-ft work platform and was equipped with a 150-ft boom and crane to support the coring device. Once the barge was in position, 60-ft spud anchors were lowered to maintain that position. Crowley Dock, operated by Crowley Marine, was used as the staging area for all coring operations.

Land and Sea Surveys of Ventura, California, provided navigational support throughout the coring operations. Land and Sea used a Geodimeter laser/range azimuth positioning system to locate the coring stations. Navigational survey control points were located at the Union Pacific Railroad Yard (California State Coordinates - Zone III - N478193.85, E1471745.84), Monument Chan (California Coordinates - N474967.18, E1479560.29), and the Crowley Marine Dock in the

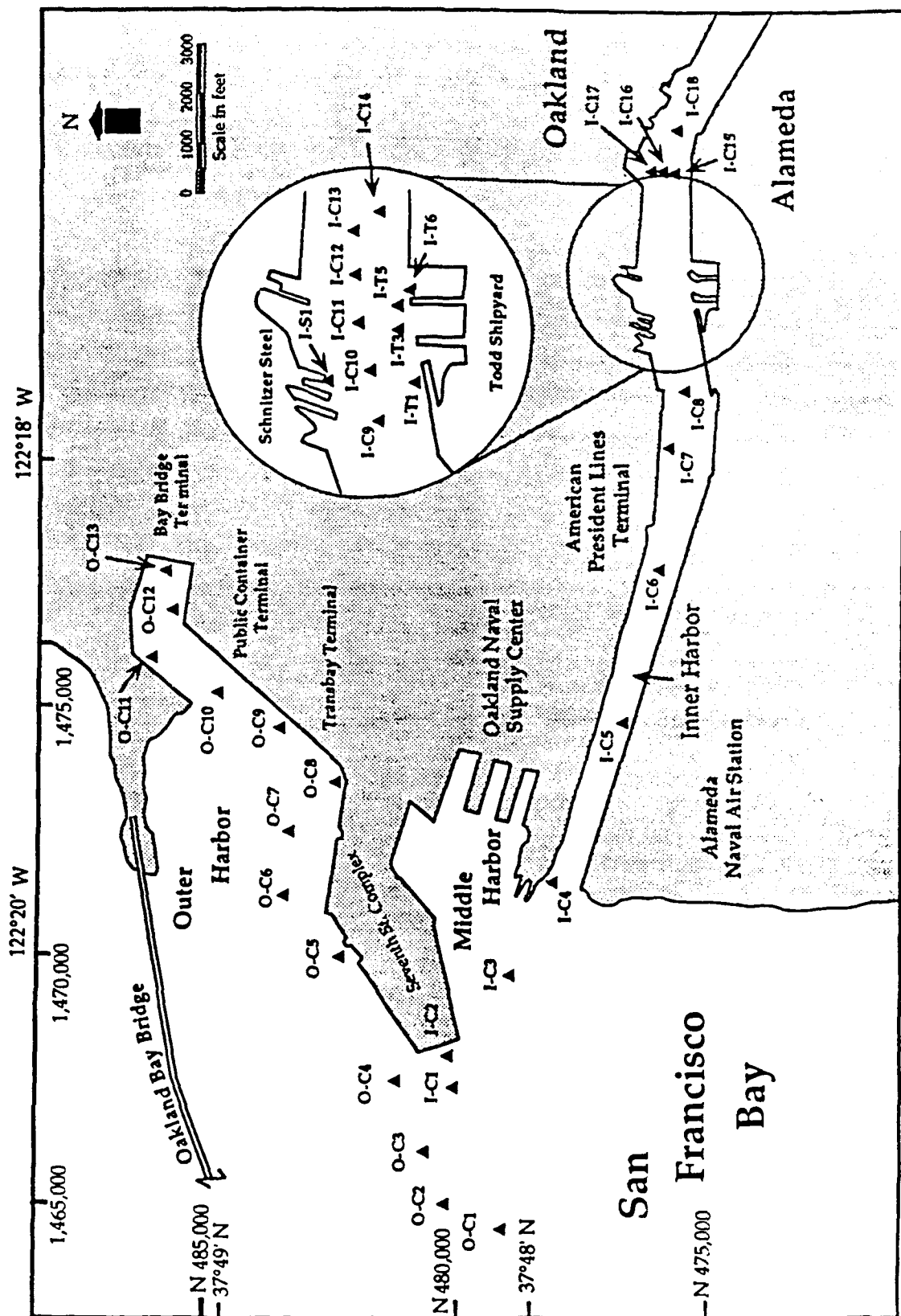


FIGURE 2.1. Oakland Phase III A Inner and Outer Harbor Sampling Stations

TABLE 2.1. Sediment Sample Identification Codes and Analyses

Sediment Treatment Identification	Sediment Treatments for Chemical Analysis	Sediment Treatments for Biological Analysis		
		SP ^(a)	SPP ^(b)	WES ^(c)
<u>Oakland Inner Harbor Stations</u>				
I-C1	---(d)	---	---	AC-1(e)
I-C2	---	---	---	AC-1
I-C3	I-C3	I-C3	---	AC-1
I-C4	I-C4	I-C4	---	AC-1
I-C5	I-C5	I-C5	---	AC-1
I-C6	---	---	---	AC-1
I-C7	I-C7	I-C7	---	AC-1
I-C8	I-C8	I-C8	---	AC-1
I-C9	I-C9	I-C9	BC-4	AC-1
I-C10	I-C10	I-C10	BC-4	AC-1
I-C11	I-C11	I-C11	BC-4	AC-1
I-C12	I-C12	I-C12	BC-4	AC-1
I-C13	---	---	---	AC-1
I-C14	I-C14	I-C14	BC-3	AC-1
I-C15	I-C15	I-C15	BC-3	AC-1
I-C16	I-C16	I-C16	BC-3	AC-1
I-C17	I-C17	I-C17	BC-3	AC-1
I-C18	I-C18	I-C18	BC-3	AC-1
I-S1	I-S1	I-S1	---	---
I-T1	I-T1	I-T1	---	---
I-T3	I-T3	I-T3	---	---
I-T5	I-T5	I-T5	---	---
<u>Oakland Outer Harbor Stations</u>				
O-C1 through O-C13	---	---	---	AC-3(e)

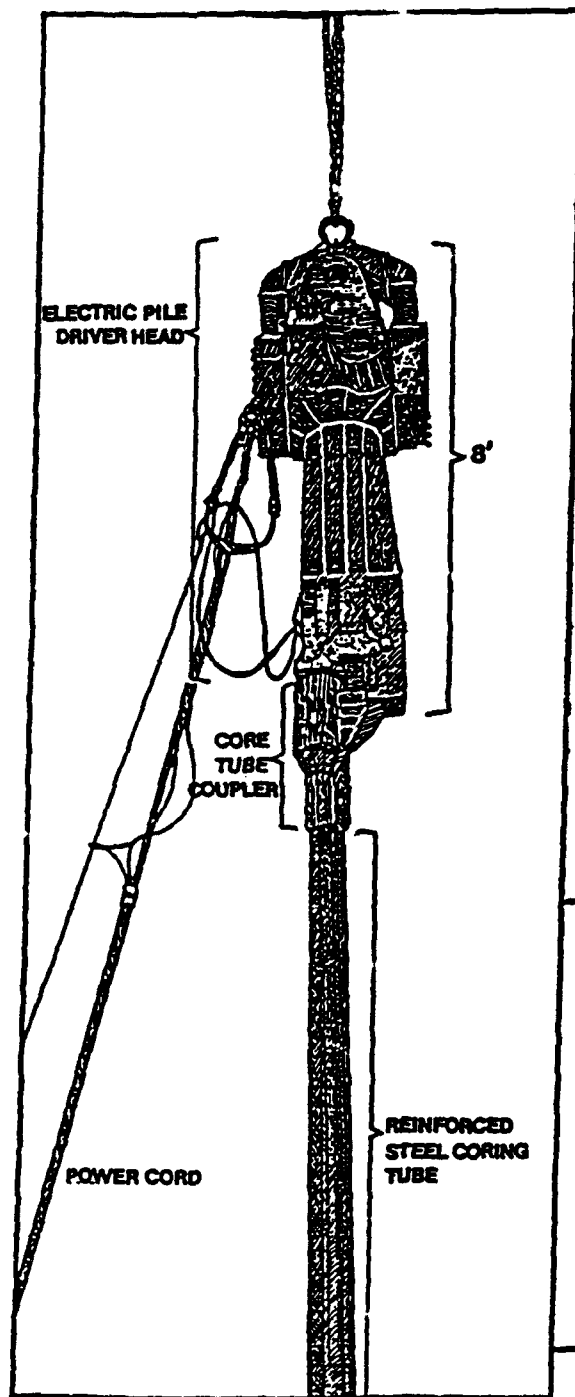
(a) Solid-phase toxicity test.

(b) Suspended-particulate-phase toxicity test.

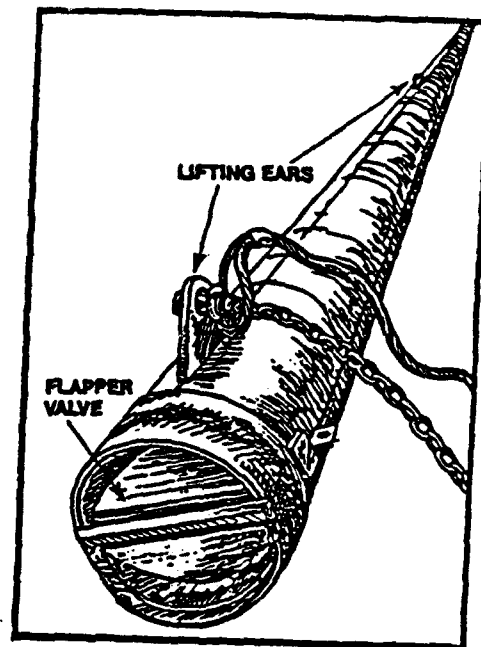
(c) Waterways Experimental Station evaluation.

(d) Sediment treatment not used for this analysis at the direction of USACE.

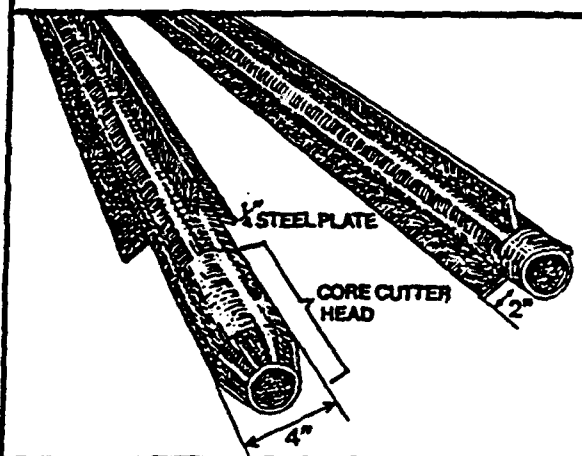
(e) This composite station received chemical and grain size analysis and solid-phase toxicity testing.



Vibratory-Hammer Core



12-in. Coring Device



4-in. Coring Device

FIGURE 2.5. Components of the 4-in. and 12-in. Vibratory-Hammer Coring Devices

vicinity of Todd Shipyard (California Coordinates - N475303.82, E1483103.14). An additional point was used to site the maneuvering area (N475348.26, E1483606.00).

Prior to coring, navigators surveyed the station reference coordinates, deployed station buoys, and determined station water depths with a calibrated fathometer. The uncorrected depth, determined with the fathometer, was recorded in station logs kept by Land and Sea Surveys. Depth corrections were made during the coring operation by measuring water level with respect to a known tidal benchmark (e.g., Monument Chan is 10.39 ft above MLLW) and applying the appropriate correction factor to the depth measured from the coring barge at that time. By eliminating the use of a tide table, errors resulting from tide table corrections were reduced. However, to check corrected MLLW depths provided to the derrick barge by Land and Sea Surveys personnel, tide tables were compared to MLLW water depths in the coring area during coring operations. Uncorrected water depths and verified MLLW depths were recorded in MSL field logs. Water depth information was used to calculate the total core length required to penetrate the substrate to the project depth of -42 ft (plus 2 ft overdepth).

After the *Hagar* was positioned and the MLLW depths verified, the station buoy offset was determined to permit the coring device to be positioned correctly. To collect a sample, the core sampler was suspended from the crane on the derrick barge, and the crane was used to lower the sampler to the sediment. As the coring device was lowered to the seafloor, the coring depth was measured using the calibration marks on the core barrel. If the weight of the sampler itself did not cause it to penetrate the sediment to -44 ft MLLW (project depth of -42 ft MLLW plus 2 ft overdepth), the core sampler was driven to depth by a 6-ton, Westam electric vibratory hammer. The core barrel was then lifted from the sediment by the crane, decoupled from the vibratory hammer, and lowered onto the deck of the barge.

The 4-in.-diameter sampler was used to collect cores from the Oakland Harbor sites for geological description, chemical analysis, and toxicological testing. The 4-in. core barrel was lined with a length of steam-cleaned Lexan polycarbonate tubing that protected the sediment from disturbance and contamination during sampling. Sediment was retained in the Lexan core liner either by specially designed core catchers or a flapper valve (Figure 2.5). When the sampler was brought onto the barge, the Lexan liner containing the sediment was pulled from the sampler and measured to confirm that sufficient depth was reached. The core was then capped at both ends and labeled. If necessary, samples were cut and capped in shorter sections to fit inside the storage freezer on board the *D/B Hagar*, where all core samples were stored at approximately 4°C. Sediment composite sites AC-1 and AC-3 were consolidated by mixing sediment from the 4-in.

cores in large cement mixers at the MSL. These composite stations received chemical and grain size analysis and solid-phase toxicity testing.

Many of the Phase III A samples were collected using a sampler with two 4-in.-diameter core barrels. The obvious advantage of the double-barreled sampler is that it permits collection of duplicate core samples simultaneously. However, the double-barreled core sampler operates optimally only when both core barrels enter the sediment at exactly the same angle. Penetration of the double core through the sediment when the barrels are slightly bent was much slower than it was for the single core.

The 12-in. split-core sampler yields approximately 5.8 gal of sediment per running foot, so it was used to collect the large volumes of sediment needed for the WES uplands/wetlands and FATES testing programs. The 12-in. sampler was split longitudinally for approximately 30 ft, with the two halves connected by hinged "doors," each approximately 10 ft long. The upper door was welded shut most of the time, but was cut open when a longer core was needed. The lower door was held shut by chain binders during sampling. Sediment was retained in the 12-in. split core either by the strength of the compact sediment at the bottom or by a specially designed flapper valve. When a 12-in. core was brought on deck, the lower door was unchained and pried open to expose the sediment. The length of the core was measured and recorded. If sufficient sediment was collected, the sediment from the appropriate depth fraction (mudline to -44 ft MLLW) was shoveled into a labeled, epoxy-coated 55-gal drum. The drums were kept covered at all times unless actively being filled. The core sampler was thoroughly rinsed with seawater between samples. Processing of WES sediment samples took place on board the *Hagar*. Sediment from the 12-in. cores was collected and composited to make stations AC-1 (Oakland Inner Harbor) and AC-3 (Oakland Outer Harbor). These composite stations received chemical and grain size analysis and solid-phase toxicity testing. Sediment from the 12-in. cores was also sent to WES and composited into station AC-1 for their testing. A subsample of these composites was sent to the MSL at the end of the Phase III A testing. This sample was tested in August 1990 with several others that were collected from San Francisco Bay for WES.

Sampling took place at Oakland Inner and Outer Harbors from June 4 through 13, 1990. A total of 128 acceptable cores were collected at 35 stations, as shown in Figure 2.1. Mudline depths (as evidenced by the ring of mud surrounding the core barrel) at the sampling locations varied from -25.4 ft MLLW (Station T-5) to -41.5 ft MLLW (Station OC-2), resulting in core lengths of 18.6 ft and 2.5 ft, respectively. The minimum sediment volume required for each sediment treatment (60 L) was obtained with 28.0 ft of core from the 4-in.-diameter core. All stations were

successfully cored to the project depth. Field data for coring operations are summarized in Volume 2, Appendix A.

2.1.2. Reference and Control Sediment Collection

The F/V *Cobra* was used for collection of the San Francisco Bay, offshore, and off-shelf reference sediments. Disposal site reference sediment was collected with a 0.1-m² modified van Veen grab sampler from three areas within San Francisco Bay. A summary of the sampling data is provided in Volume 2, Appendix A. Six sampling stations (designated R-BF 1 through R-BF 6) were located within the Bay Farm Borrow Area (Figure 2.2). Eight stations (designated R-AC 1 through R-AC 8) were located within a circle having a diameter of approximately 0.3 nmi, whose center is located 0.25 nmi south of Alcatraz Island. This circle is the Alcatraz Island Dredged Sediment Disposal Site (Figure 2.3). Nine stations (designated R-AM A through R-AM I) were located on a grid surrounding Alcatraz Island at locations presumably not affected by the disposal of dredged material (Figure 2.3). Sampling stations were located by using a combination of LORAN C and variable fix and range radar, as well as fixes to identifiable shore ranges. Sediment from the grab samples was placed into coolers and stored at 4°C until transferred to the refrigerated truck and transported to the MSL for chemical analysis and bioassay testing. Sediment from all stations within an area was sieved through a 0.5-mm screen and composited before use.

Two types of offshore reference sediments were collected from an area south of Point Reyes, California (Figure 2.4), and one farther offshore (Figure 1.1). Six samples were collected with a large pipe dredge from an area of silty sediment (fine reference) and composited (designated R-PF). Nine samples were collected from an area of sandy material (coarse reference) and composited (designated R-PC). The off-shelf dredge sample (designated R-OS) was taken at a depth of about 4200 ft from an area approximately 40 nmi west of Half-Moon Bay, California.

Native control sediments were collected from three areas: Sequim Bay, Washington (designated C-SB); West Beach on Whidbey Island, Washington (designated C-WB); and Tomales Bay, California (designated C-NE). About 156 L of native sediment for *M. nasuta* were collected from Sequim Bay (Figure 2.6) using a modified van Veen grab sampler. A small dredge was used to collect approximately 50 L of native sediment for *R. abronius* from West Beach (Figure 2.7) in waters about 15 ft deep. Sequim Bay and West Beach sediments were placed into coolers and transported to MSL on the day of collection. Native sediments for *N. caecoides* were collected from Tomales Bay (38°13.83'N, 122°57.67'W) (Figure 2.8), placed in coolers, and transported overnight to MSL. Each native sediment was washed through a sieve with mesh openings of 0.5-mm to remove larger predatory animals and debris. Additionally, the Tomales Bay sediment

was vigorously aerated in a flow-through tank prior to use in testing to aerate the organically rich sediment.

2.1.3 Sample Shipment

The test sediment samples collected in Oakland Inner Harbor were held in 4-in. core tubes. The reference and control sediments were contained in coolers. Each day after the samples were collected they were off-loaded into a refrigerated van and stored at 4°C. Chain-of-custody forms were completed in the field, sealed in plastic bags, and attached to one of the coolers. When all sampling was completed, samples for WES were shipped to Vicksburg, Mississippi, in one refrigerated van maintained at 4°C. Samples for the MSL were shipped to Sequim, Washington, in another refrigerated van maintained at 4°C. Once at the MSL, samples were held at 4°C until used for chemistry or bioassay testing. Upon receipt the samples were inventoried against chain-of-custody forms and maintained in the refrigerated van. All samples were used within their 2-week holding limit.

2.2 TEST ORGANISM COLLECTION

Six different species of marine organisms were used for the Oakland Phase III A sediment evaluations:

- Bent-nose clam (*Macoma nasuta*)
- Marine worm (*Nephtys caecoides*)
- Marine amphipod (*Rhepoxynius abronius*)
- Sanddab (*Citharichthys stigmaeus*)
- Mysid shrimp (*Holmesimysis sculpta*)
- Oyster larvae (*Crassostrea gigas*)

These animals were obtained before and during sediment collection operations.

2.2.1 M. nasuta Collection

Approximately 10,000 individuals of the bent-nose clam, *M. nasuta*, were collected in Discovery Bay, Washington, (48°02.80'N, 122°50.00'W) by Johnson and Gunstone Clams of Port Townsend, Washington. Discovery Bay is located near the MSL, and is considered an uncontaminated habitat for *M. nasuta* (EPA 1986a). Clams were collected with a shovel, sieve, and bucket. Care was taken to minimize shell breakage. In the field, clams were kept cool in large

APPENDIX A.

Sediment Chemical Characterization

KEY

	<u>Battelle Code</u>	<u>Sponsor Code</u>
Oakland Inner Sediment -	206-1	OIW-S1
	206-2, Rep. 1	OIW-S2
	206-2, Rep. 2	OIW-S2, duplicate
	206-3	OIW-S3
 Oakland Outer Sediment -	 206-4	 OOW-S1
	206-5	OOW-S2
	206-6	OOW-SW (3)

206SED

SEDIMENT DATA

Project: OAKLAND INNER/OUTER
Sponsor: SKOGERBOE

(CF#206)

6/6/91

SEDIMENT METAL DATA

(Concentrations in mg/kg dry wt.)

Sample Code	Sponsor Code	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
206-1	OIW-S1	0.11	6.86	0.15	444.0	24.7	0.145	64.0	12.2	0.19	61.0
206-2, Rep. 1	OIW-S2	0.12	6.45	0.15	383.0	22.8	0.11	64.6	14.9	0.18	60.5
206-2, Rep. 2	OIW-S2	0.12	4.73	0.17	388.0	26.7	0.102	69.0	15.3	0.19	64.7
206-3	OIW-S3	0.09	4.44	0.12	310.0	23.9	0.082	63.2	14.2	0.15	58.2
206-4	OOW-S1	0.19	6.02	0.23	388.0	32.5	0.159	83.3	19.6	0.23	82.1
206-5	OOW-S2	0.20	7.35	0.23	357.0	30.6	0.162	81.0	18.9	0.30	87.3
206-6	OOW-SW	0.22	7.33	0.24	347.0	30.1	0.177	87.8	17.5	0.27	85.0
206-7	OW-S	0.09	11	0.32	68.0	20.1	0.078	34.3	26.8	0.54	131.3
Procedural Blank		0.02	NA	0.015U	NA	NA	0.017	NA	NA	0.012U	NA

Standard Reference Material:

MESS-1 (10/16)			11.9	0.59	76.0	26.6	0.19	30.6	32.9	0.39	179.4
MESS-1 (10/19)			10.9	0.61	82.0	26.5	NA	30.8	34.2	0.38	170.2
MESS-1 (10/22)			10.3	NA	80.0	24.0	NA	33.0	34.0	NA	183.4
Certified	NC		10.6 (+/- 1.2)	0.59 (+/- 0.1)	71.0 (+/- 11)	25.1 (+/- 3.8)	0.171 (+/- 2.7)	29.5 (+/- 6.1)	34.0 (+/- 0.06)	0.34 (+/- 0.17)	191

1546			NA	0.33	NA	NA	NA	NA	NA	0.64	NA
Certified	NC			0.36 (+/- 0.07)						-0.6	

PACS-1											
Certified	NC		211 (+/- 1.2)	2.38 (+/- 0.2)	113.0 (+/- 8)	452.0 (+/- 16)	4.57 (+/- 0.16)	12.9 (+/- 2)	404.0 (+/- 20)	1.09 (+/- 0.11)	824.0 (+/- 22)

U Indicates not detected at detection limit shown

NC Indicates not certified

NA Indicates not analyzed

206SED

12/12/90

(CF#206)

SEDIMENT DATA

Project: OAKLAND INNER/OUTER
Sponsor: SKOGERBOE

SEDIMENT BUTYLtin RESULTS

(Concentrations in ug/kg Dry Wt.)

Sample Code	Sponsor Code	TETRA-BUTYLtin	TRI-BUTYLtin	DI-BUTYLtin	MONO-BUTYLtin	% Surrogate Recovery PROPYLtin
206-1	OIW-S1	<0.4	5.6	3.9	<0.4	45%
206-2, Rep. 1	OIW-S2	<0.4	5.4	4.9	<0.4	32%
206-3	OIW-S3	<0.5	4.2	4.8	0.6	34%
206-4	OOW-S1	<0.5	2.8	3.4	1.7	26%
206-5	OOW-S2	<0.5	2.7	2.5	<0.5	27%
206-6	OOW-SW-3	<0.6	3.1	1.6	0.8	49%
METHOD BLANK	METHOD BLANK	<0.6	<0.6	<0.5	<0.5	58%

NA indicates data not available.

206SED

12/12/90

(CF#206)

SEDIMENT DATA

Project: OAKLAND INNER/OUTER

Sponsor: SKOGERBOE

SEDIMENT PAH DATA

(Concentrations in ug/kg Dry Wt.)

OIW-S1	OIW-S2	OIW-S3	OOW-S1	OOW-S2	OOW-SW	METHOD
214575	214576	214577	214572	214573	214575	BLANK

Sponsor Code :
TCT Code :

NAPHTHALENE	8	7	9	11	9	4	3.6
ACENAPHTHYLENE	4	3	3	4	4	2	< 0.32
ACENAPHTHENE	5	5	5	5	5	2	< 0.8
FLUORENE	3	3	3	5	5	2	< 0.64
PHENANTHRENE	25	29	19	25	31	15	< 0.87
ANTHRACENE	7	9	5	10	10	5	< 0.37
FLUORANTHENE	81	73	59	61	60	29	< 0.53
PYRENE	139*	126*	105	106	98	48	0.58
BENZ[ANTHRACENE	48	42	35	52	44	24	< 0.37
CHRYSENE	51	42	42	55	61	35	< 0.32
BENZOFUORANTHENE*	180	135	143	167	149	80	< 0.4
BENZO[APYRENE	123*	98*	109	123	101	52	< 0.32
INDENO[1,2,3-cd]PYRENE	73*	90	95	129	106	40	< 0.51
DIBENZ[ah]ANTHRACENE	19	16	16	20	17	7	< 0.29
BENZO[ghi]PERYLENE	113*	74*	142	171	137	51	< 0.25
SURROGATE RECOVERY:							
D10-FLUORENE	112%	106%	110%	115%	115%	117%	133%
D10-ANTHRACENE	80%	80%	78%	80%	88%	90%	86%
D10-PYRENE	70%	69%	65%	64%	66%	62%	75%

* All benzofluoranthene isomers (b,j and i) are quantified together.

** Represents value calculated from a 1:10 dilution.

SEDIMENT DATA

Project: OAKLAND INNER/OUTER
Sponsor: SKOGERBOE

(CF#206)

8/24/91

SEDIMENT PESTICIDE DATA

(Concentrations in ug/kg Dry Wt.)

Sponsor Code :
TCT Code :

PESTICIDES	OIW-S1 214575	OIW-S2 214576	OIW-S3 214577	OOW-S1 214572	OOW-S2 214573	OOW-SW 214575	METHOD BLANK
ALDRIN	<3	<3	<3	<3	<3	<3	<2
A-BHC	<3	<3	<3	<3	<3	<3	<2
B-BHC	<3	<3	<3	<3	<3	<3	<2
D-BHC	<3	<3	<3	<3	<3	<3	<2
CHLORDANE	<3	<3	<3	<3	<3	<3	<2
4,4'DDD	<3	<3	<3	<3	<3	<3	<2
4,4'DDE	<3	<3	<3	<3	<3	<3	<2
4,4'DDT	<3	<3	<3	<3	<3	<3	<2
ENDOSULFAN I	<3	<3	<3	<3	<3	<3	<2
ENDOSULFAN II	<3	<3	<3	<3	<3	<3	<2
EDOSULFAN SULFATE	<3	<3	<3	<3	<3	<3	<2
ENDRIN	<3	<3	<3	<3	<3	<3	<2
ENDRIN ALDEHYDE	<3	<3	<3	<3	<3	<3	<2
HEPTACHLOR	<3	<3	<3	<3	<3	<3	<2
HEPTACHLOR EPOXIDE	<3	<3	<3	<3	<3	<3	<2
LINDANE (G-BHC)	<3	<3	<3	<3	<3	<3	<2
TOXAPHENE	<27	<26	<27	<31	<31	<27	<20
METHOXYCHLOR	<5	<5	<5	<6	<6	<5	<4
ENRIN KETONE	<3	<3	<3	<3	<3	<3	<2
SURROGATE RECOVERY (DBC):	92%	87%	97%	110%	100%	92%	75%

< Indicates analyte not detected above detection limit shown.

SEDIMENT DATA

Project: OAKLAND INNER/OUTER
Sponsor: SKOGERBOE

(CF#206)

12/12/90

SEDIMENT PCB DATA

(Concentrations in ug/kg Dry Wt.)

Sponsor Code :
TCT Code :

OIW-S1	OIW-S2	OIW-S3	OOW-S1	OOW-S2	OOW-SW	METHOD
214575	214576	214577	214572	214573	214575	BLANK

PCBS						
AROCLOR 1016	<27	<26	<27	<31	<27	<20
AROCLOR 1221	<27	<26	<27	<31	<27	<20
AROCLOR 1232	<27	<26	<27	<31	<27	<20
AROCLOR 1242	<27	<26	<27	<31	<27	<20
AROCLOR 1248	<27	<26	<27	<31	<27	<20
AROCLOR 1254	<27	<26	<270	<123	<138	<20
AROCLOR 1260	<27	<26	<270	<123	<187	<20

< Indicates analyte not detected above detection limit shown.

** NOTE: Samples were screened for the presence of PCBs by Aroclor. Sample extracts will be reanalyzed for confirmation of the possible presence of individual PCB congeners. Congener data will be presented when available.

PCB QUALITY CONTROL RESULTS

SAMPLE IDENTIFICATION: 214567 Matrix Spike

<u>Compound</u>	<u>Amount Spiked (ug/mL)</u>	<u>Amount Spiked (ug/g)</u>	<u>Amount Recovered (ug/mL)</u>	<u>Amount Recovered (ug/g)</u>	<u>Percent Recovery</u>
PCB 1254	5.0	0.23	6.2	0.28	130%
Surrogate:					
DBC	--	--	--	--	150%

SAMPLE IDENTIFICATION: 214567 Matrix Spike Duplicate

<u>Compound</u>	<u>Amount Spiked (ug/mL)</u>	<u>Amount Spiked (ug/g)</u>	<u>Amount Recovered (ug/mL)</u>	<u>Amount Recovered (ug/g)</u>	<u>Percent Recovery</u>
PCB 1254	5.0	0.26	6.2	0.32	120%
Surrogate:					
DBC	--	--	--	--	120%

Date Extracted: October 23, 1990

Date Analyzed: October 24, 1990, through October 26, 1990

Laboratory No. 4410 90-7363

PESTICIDE QUALITY CONTROL RESULTS

SAMPLE IDENTIFICATION: 214558 Matrix Spike

<u>Compound</u>	<u>Amount Spiked (ug/mL)</u>	<u>Amount Spiked (ug/g)</u>	<u>Amount Recovered (ug/mL)</u>	<u>Amount Recovered (ug/g)</u>	<u>Percent Recovery</u>
Aldrin	0.50	0.026	0.53	0.027	110%
4,4' DDT	0.50	0.026	0.81	0.042	160%
Dieldrin	0.50	0.026	0.61	0.031	120%
Endrin	0.50	0.026	0.61	0.031	120%
Heptachlor	0.50	0.026	0.56	0.029	110%
Lindane (G-BHC)	0.50	0.026	0.57	0.029	110%
Surrogate: DBC	--	--	--	--	140%

SAMPLE IDENTIFICATION: 214558 Matrix Spike Duplicate

<u>Compound</u>	<u>Amount Spiked (ug/mL)</u>	<u>Amount Spiked (ug/g)</u>	<u>Amount Recovered (ug/mL)</u>	<u>Amount Recovered (ug/g)</u>	<u>Percent Recovery</u>
Aldrin	0.50	0.026	0.50	0.026	100%
4,4' DDT	0.50	0.026	0.77	0.040	150%
Dieldrin	0.50	0.026	0.35	0.018	70%
Endrin	0.50	0.026	0.54	0.028	110%
Heptachlor	0.50	0.026	0.55	0.029	110%
Lindane (G-BHC)	0.50	0.026	0.53	0.028	110%
Surrogate: DBC	--	--	--	--	130%

Date Extracted: September 19, 1990, and October 23, 1990

Date Analyzed: October 22, 1990 through October 26, 1990

Laboratory No. 4410 90-7363

SIR/PAH Matrix Spike/Matrix Spike Duplicate Recovery
Client...BATTELLE NW

Lab Name: Twin City Testing

Invoice No.: 4410 90-7363

Matrix Spiked - Client Sample No.: MSL-209-1

COMPOUND	SPIKE ADDED (ng/gram)	SAMPLE CONC. (ng/gram)	MS CONC. (ng/gram)	MS % REC #	QC LIMITS REC.
Naphthalene	34	3.8	36	93	50-150
Fluorene	34	1.7	33	90	50-150
Anthracene	34	4.7	35	87	50-150
Fluoranthene	34	44	61	48 *	50-150
Benz[a]anthracene	34	29	54	74	50-150
Benzo[a]pyrene	34	68	88	59	50-150
Benzo[ghi]perylene	34	70	122	151 *	50-150

COMPOUND	SPIKE ADDED (ng/gram)	MSD CONC. (ng/gram)	MSD % REC #	% RPD #	QC LIMITS RPD REC.
Naphthalene	34	37	97	5	50 50-150
Fluorene	34	35	97	7	50 50-150
Anthracene	34	38	99	13	50 50-150
Fluoranthene	34	69	74	42	50 50-150
Benz[a]anthracene	34	60	90	20	50 50-150
Benzo[a]pyrene	34	91	67	13	50 50-150
Benzo[ghi]perylene	34	78	24 *	144 *	50 50-150

Column to be used to flag recovery and RPD values with an asterisk

* Values outside of QC limits

RPD: 1 out of 7 outside limits

Spike Recovery: 3 out of 14 outside limits

Analyst: Daniel P. Zimmerman
 Technical Review: Jeffrey E. Perkins

COMMENTS: _____

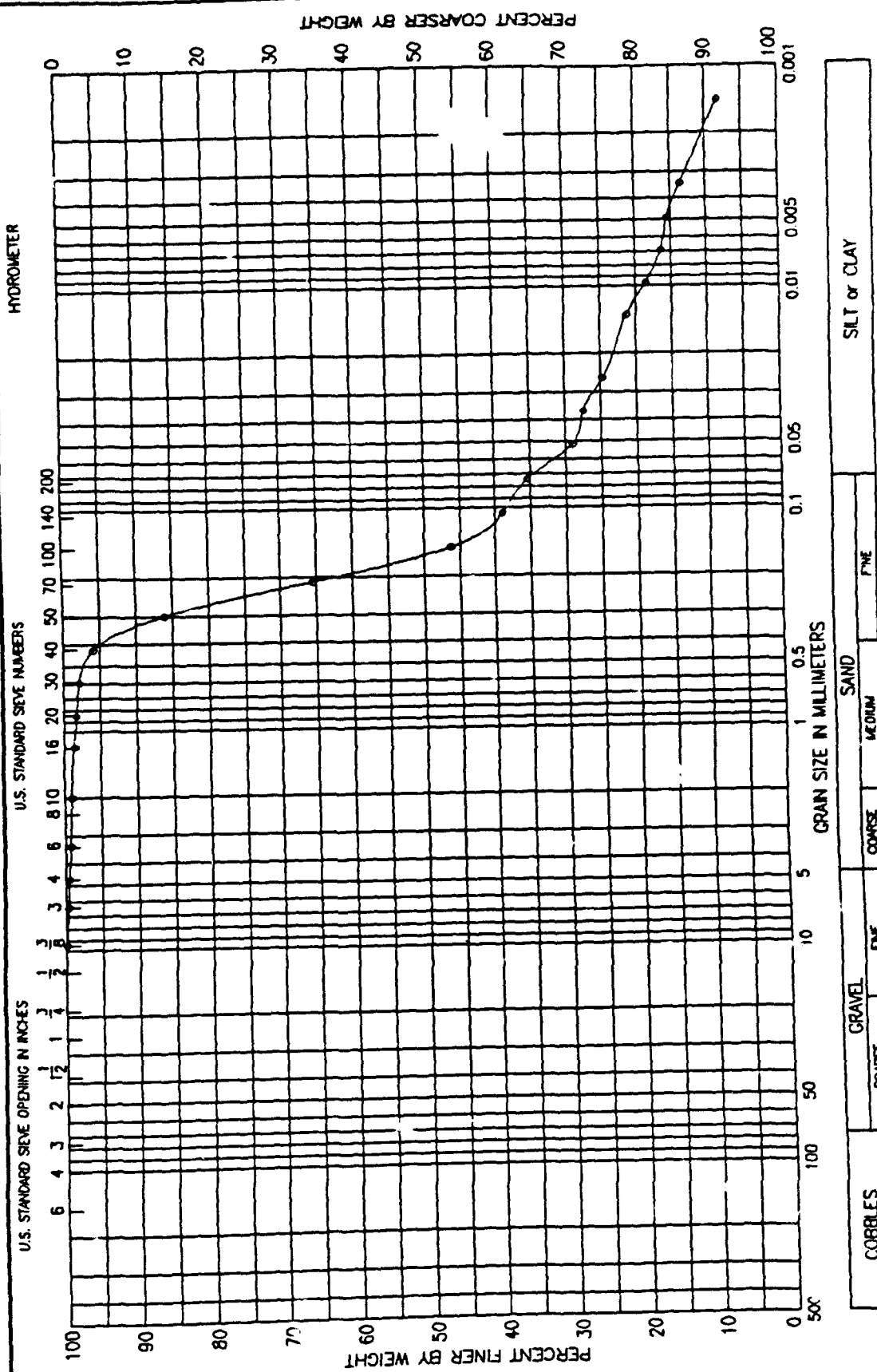
APPENDIX A.

Sediment Physical Characterization

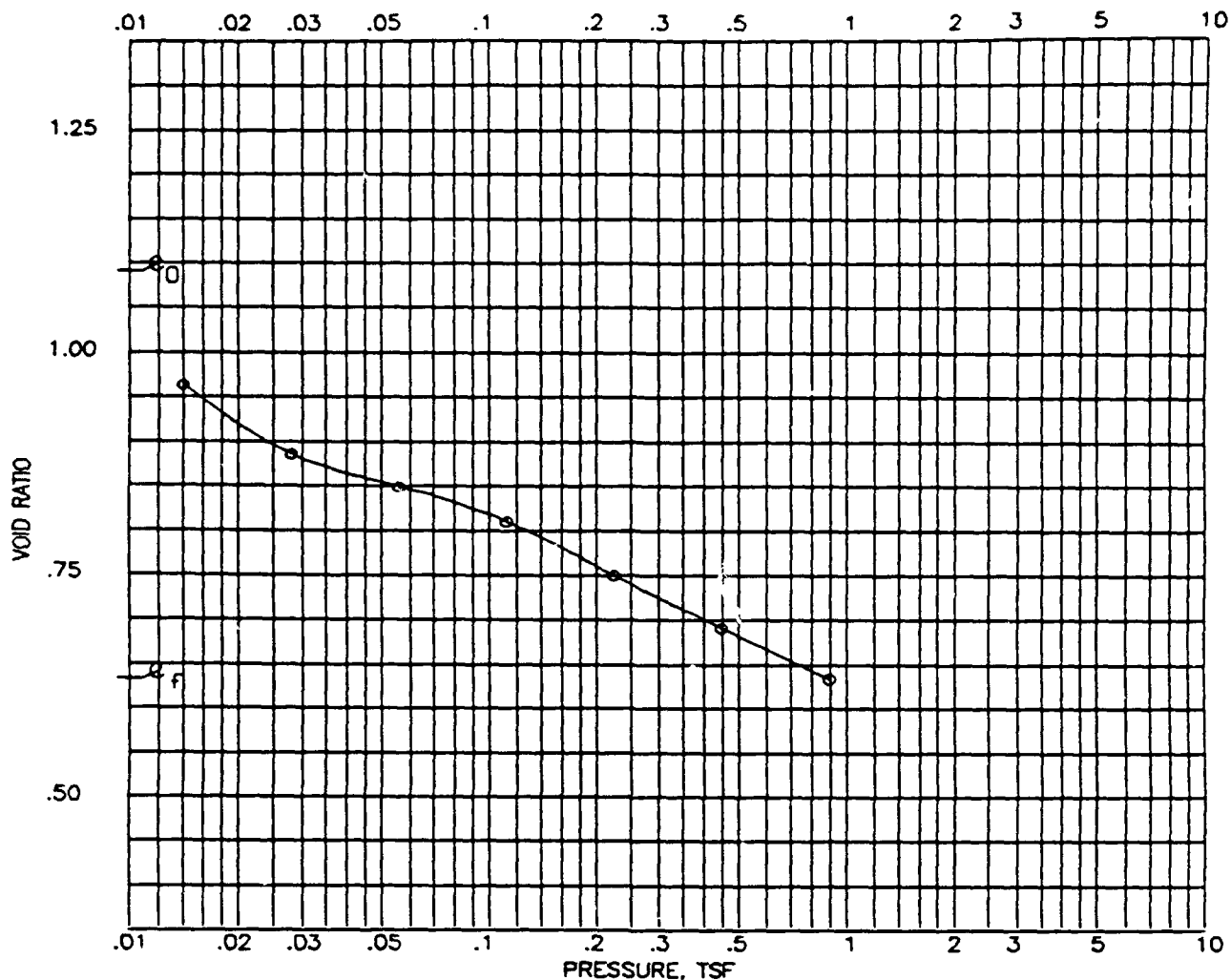
Oakland Inner

KEY

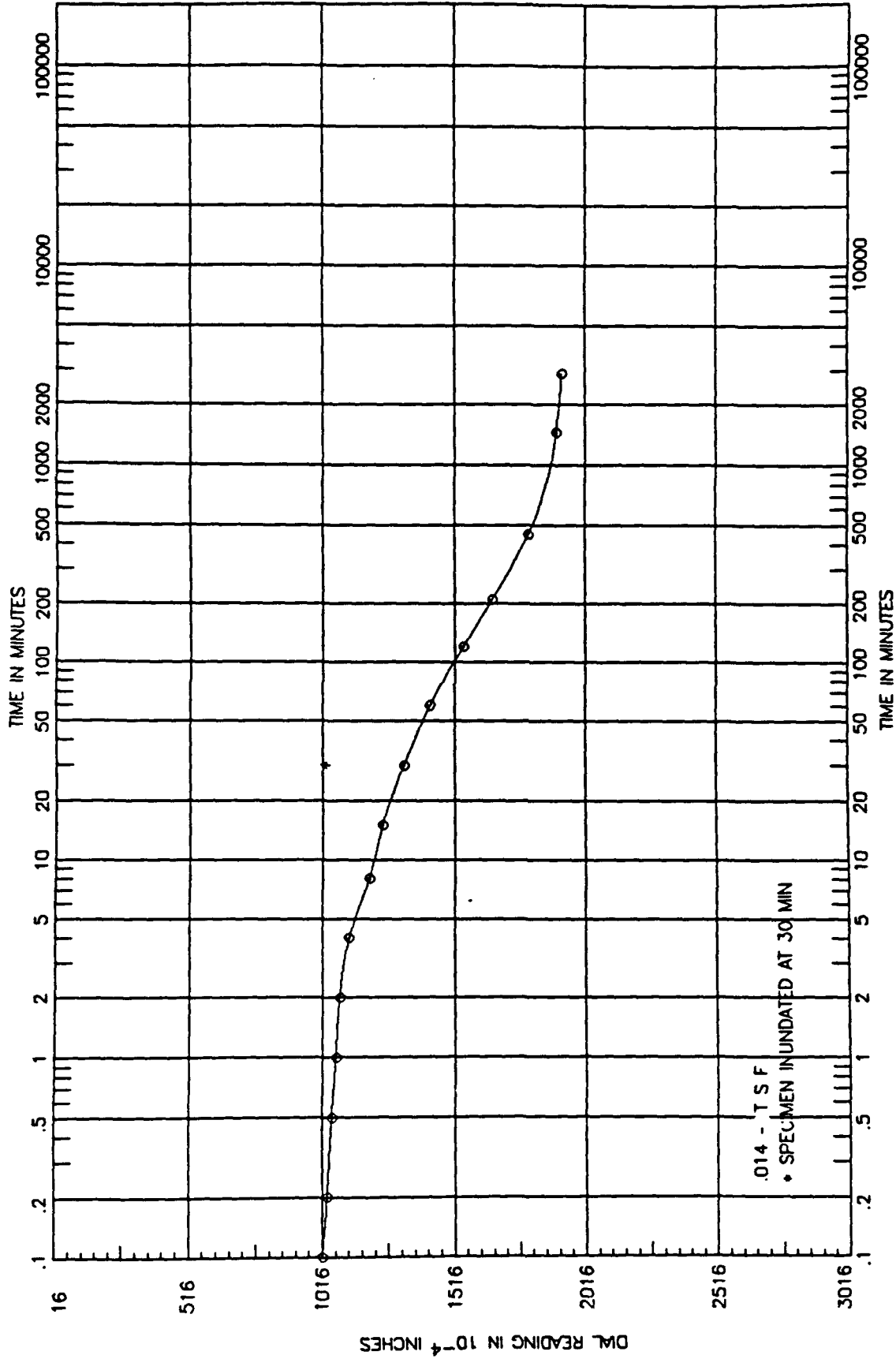
	<u>BORING NO.</u>	<u>SAMPLE NO.</u>
Oakland Inner Sediment -	Oakland	Inner
LL - Liquid Limit		
PL - Plastic Limit		
PI - Plasticity Index		
GS - Specific Gravity		
NAT W, % - % Water		



LL 27		PL 16	PI 11	GS 2.74	NAT W.% 38.9	ORG.%	PROJECT
CLASSIFICATION CLAYEY SAND (SC), GRAY							BORING NO. OAKLAND
GRADATION CURVE							DEPTH/ELEV LE
LABORATORY USAE WES - STIF/GL							SAMPLE NO. INNER
							DATE 14 JUN 91



			BEFORE TEST	AFTER TEST	
OVERBURDEN PRESSURE, TSF			WATER CONTENT, %	40.6	23.4
PRECONSOL. PRESSURE, TSF			DRY DENSITY, PCF	81.9	104.9
COMPRESSION INDEX			SATURATION, %	100 +	100 +
TYPE SPECIMEN			VOID RATIO	1.088	.631
DIA. IN 2.50		HT. IN 1.500	BACK PRESSURE, TSF		
CLASSIFICATION CLAYEY SAND (SC), GRAY					
LL 27	PL 16	PI 11	PROJECT		
GS 2.74		D ₁₀			
REMARKS:			BORING NO. OAKLAND	SAMPLE NO. INNER	
			DEPTH/ELEV LE	TECH. JAL	
			LABORATORY USAE WES - STF/GL	DATE 21 MAY 91	
			CONSOLIDATION TEST REPORT		



CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

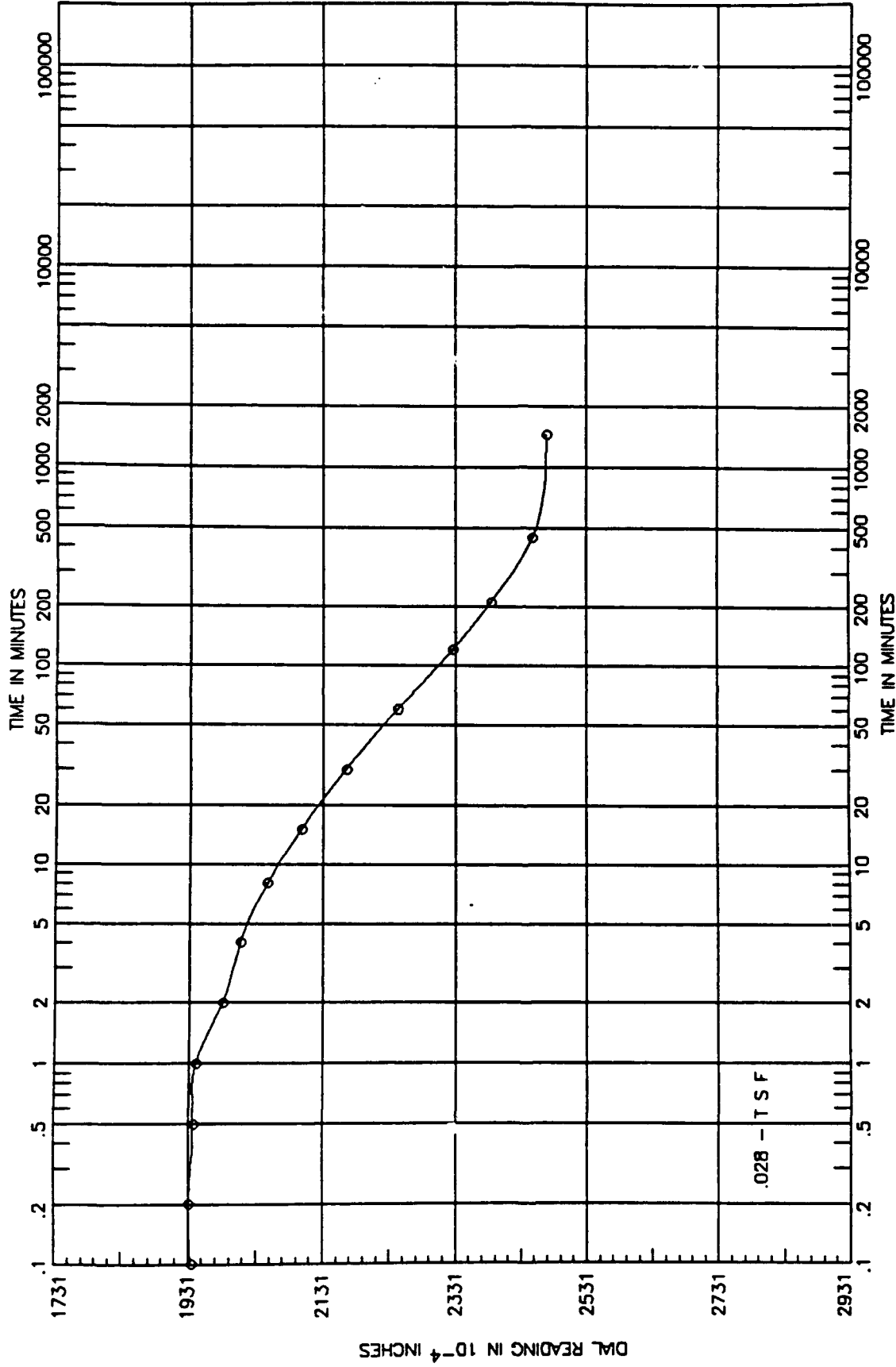
PROJECT

BORING OAKLAND

SAMPLE NO. INNER

DEPTH/ELEV LE

DATE 21 MAY 91



CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

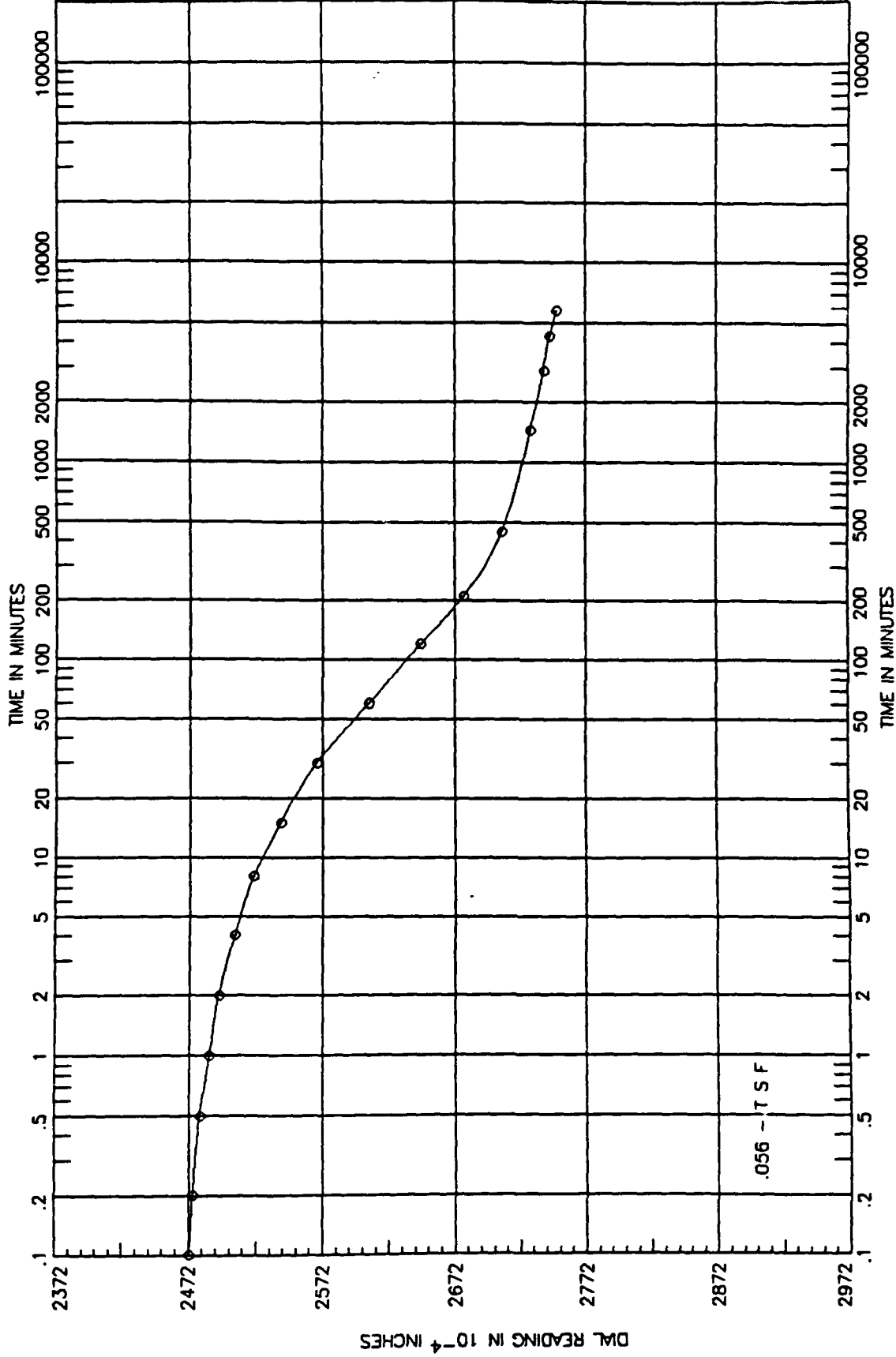
PROJECT

BORING OAKLAND

SAMPLE NO. INNER

DEPTH/ELEV LE

DATE 21 MAY 91



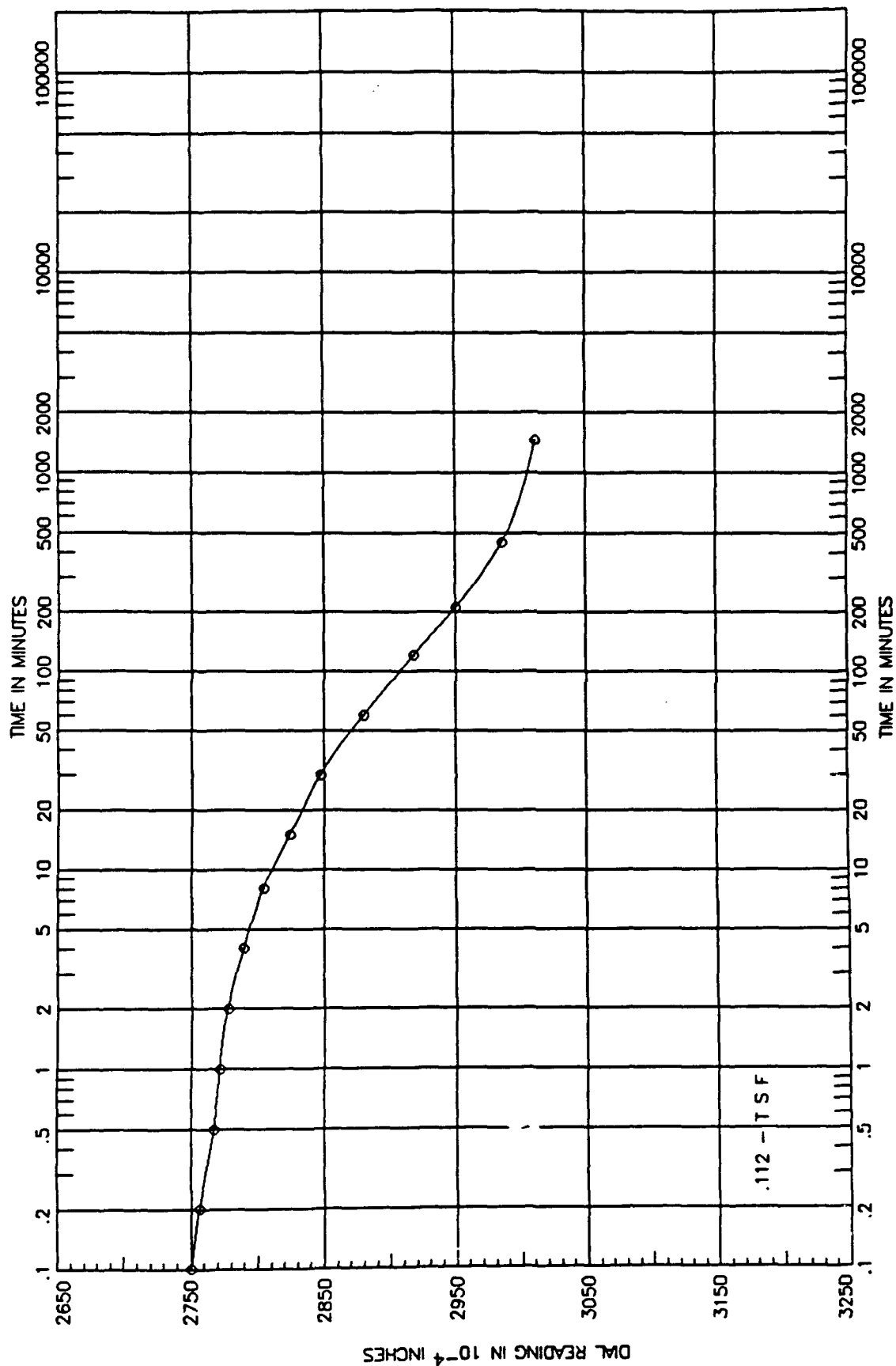
CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/G

PROJECT

BORING OAKLAND SAMPLE NO. INNER

DEPTH/ELEV LE DATE 21 MAY 91



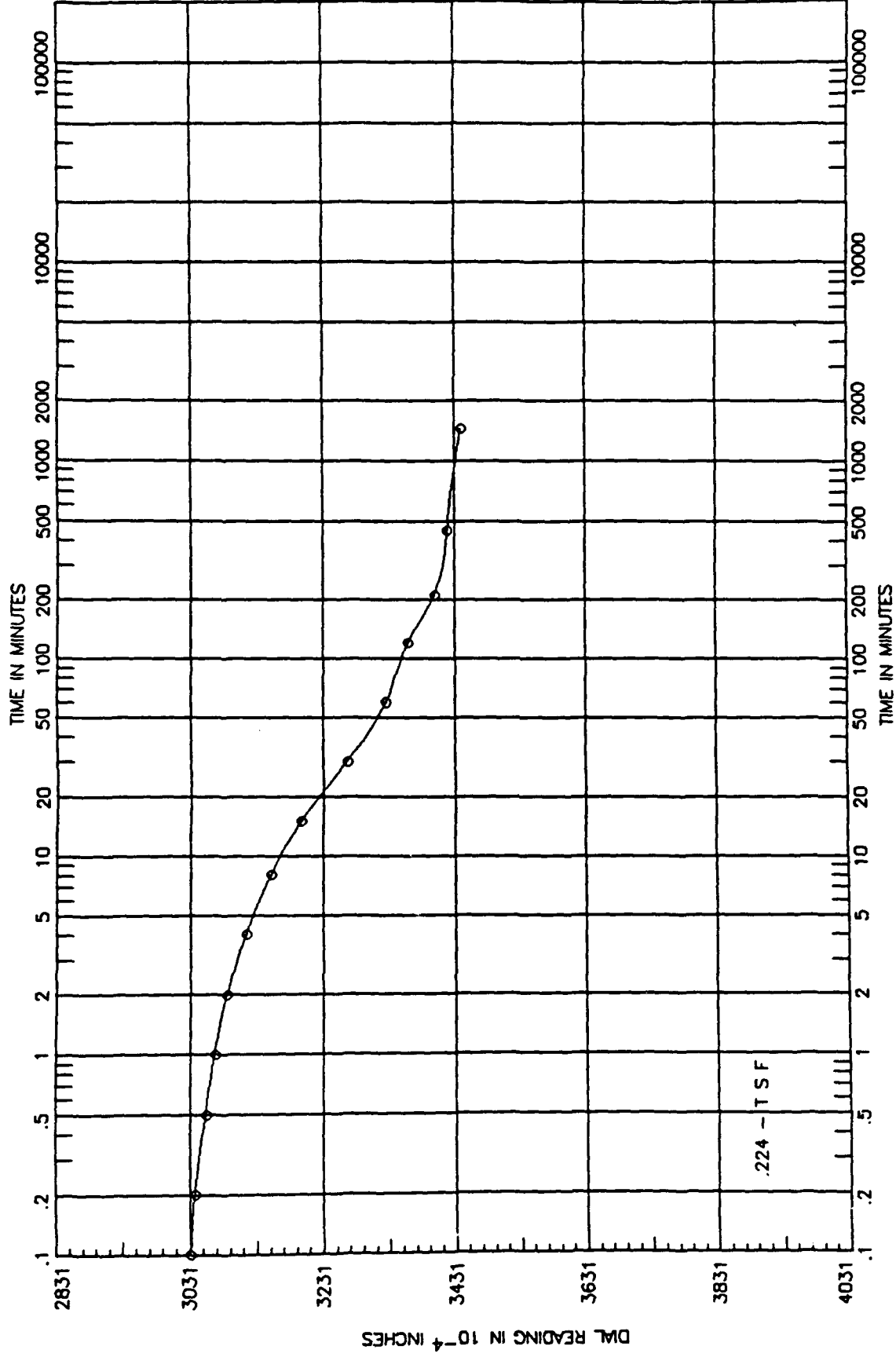
CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT

BORING OAKLAND SAMPLE NO. INNER

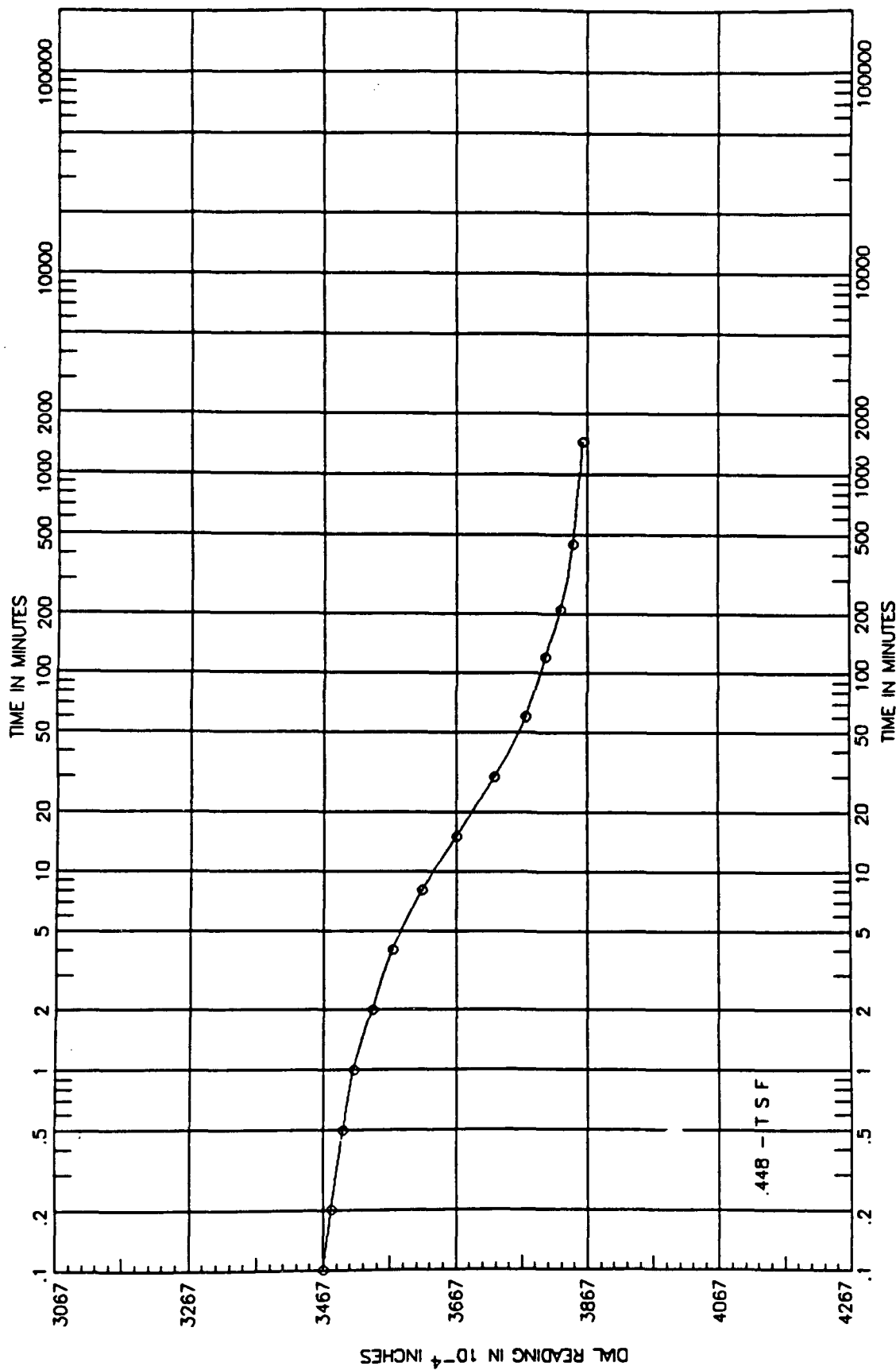
DEPTH/ELEV LE DATE 21 MAY 91



CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT	
BORING	OAKLAND
SAMPLE NO.	INNER
DEPTH/ELEV	LE
DATE	21 MAY 91



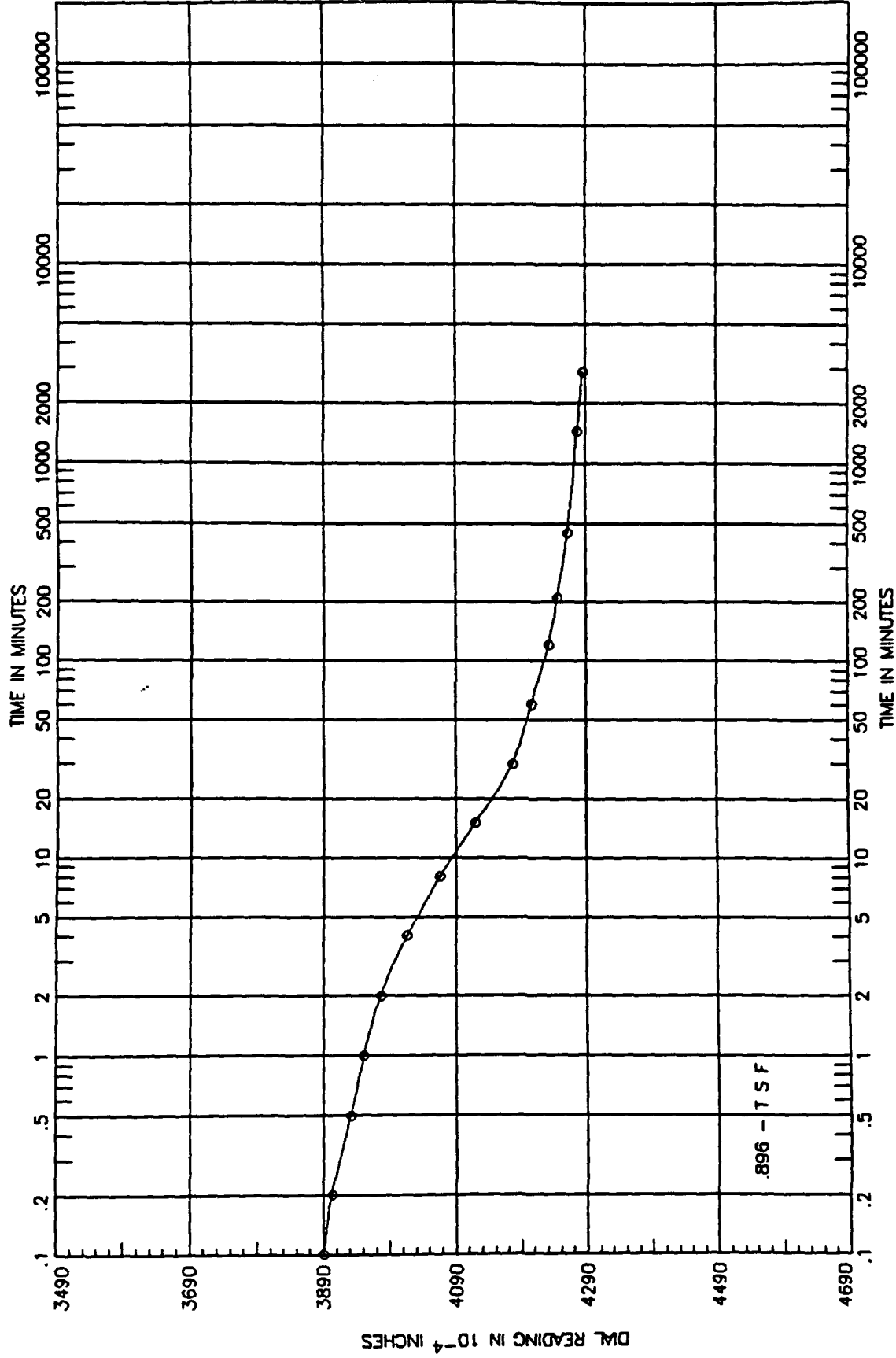
CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT

BORING OAKLAND SAMPLE NO. INNER

DEPTH/ELEV LE DATE 21 MAY 91



CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT

BORING OAKLAND SAMPLE NO. INNER

DEPTH/ELEV LE DATE 21 MAY 91

APPENDIX A.

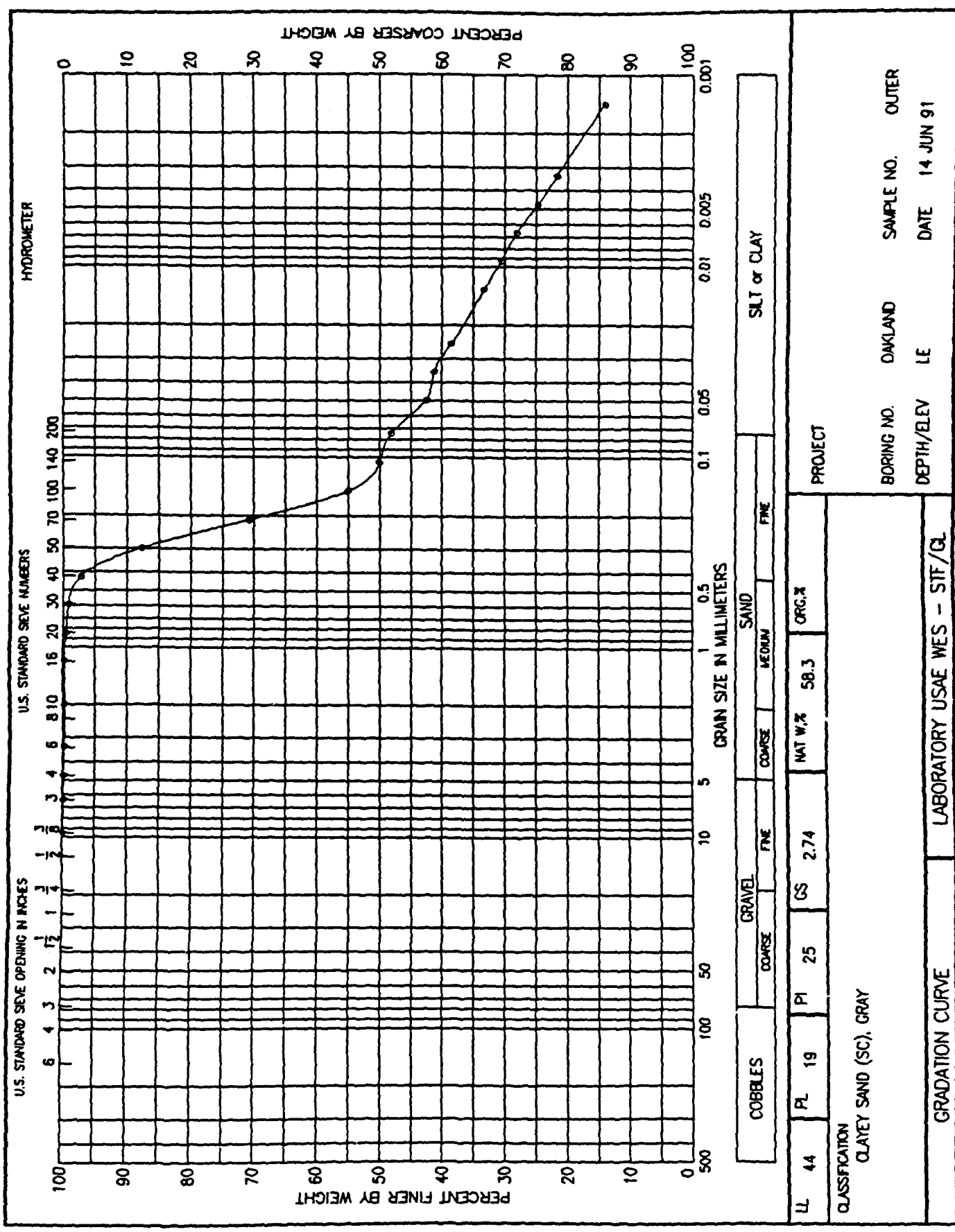
Sediment Physical Characterization

Oakland Outer

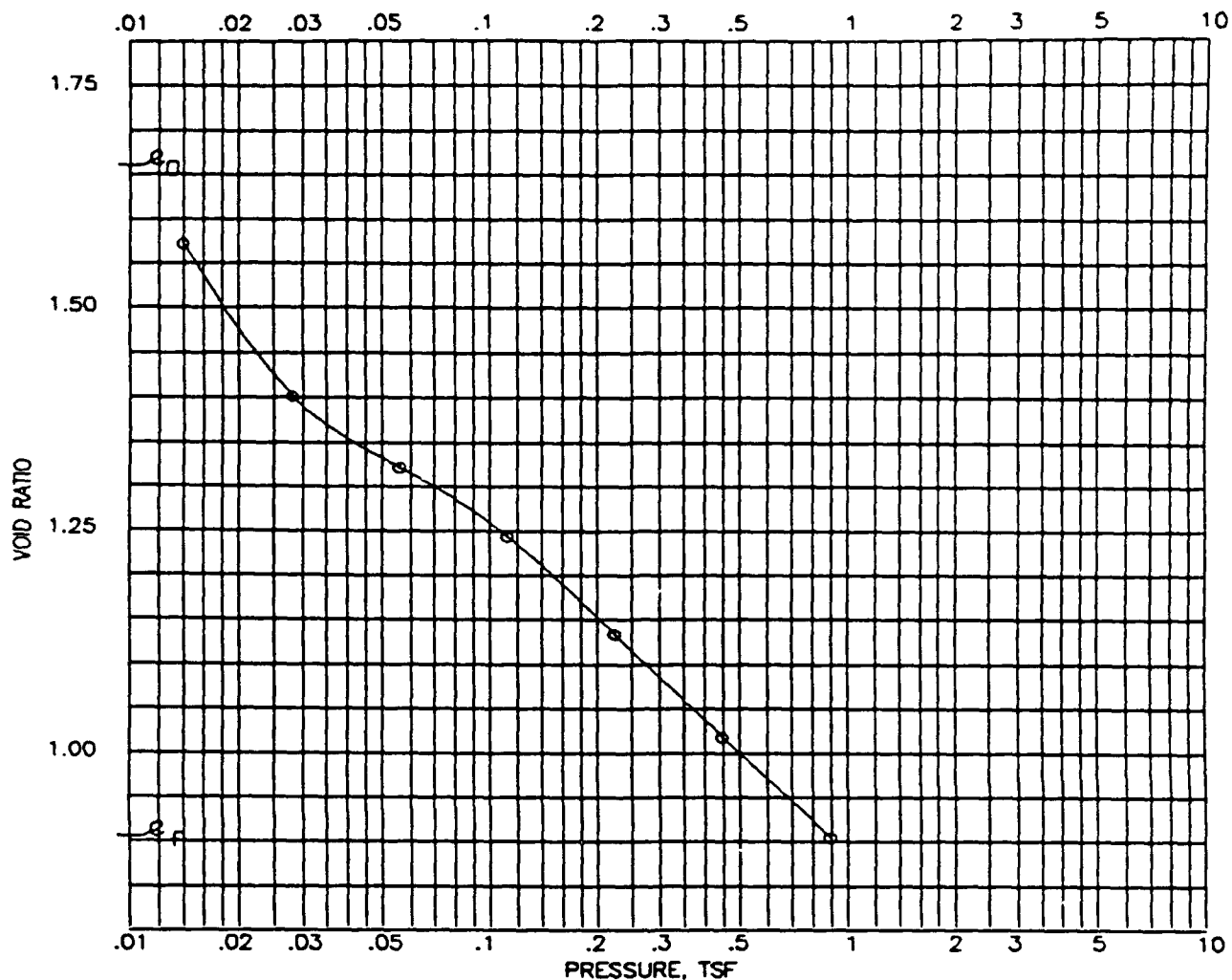
KEY

	<u>BORING NO.</u>	<u>SAMPLE NO.</u>
Oakland Outer Sediment -	Oakland	Outer

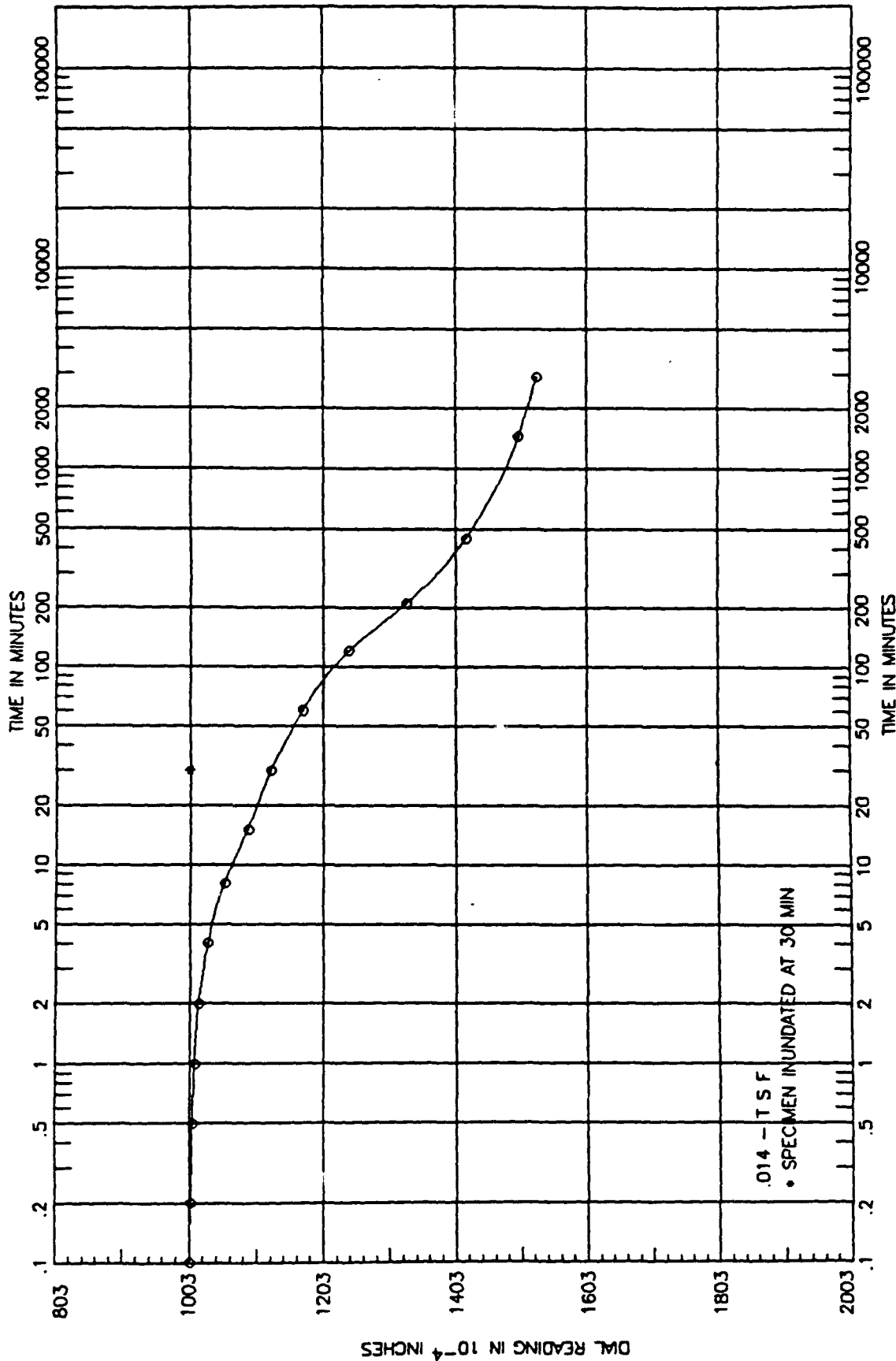
LL - Liquid Limit
PL - Plastic Limit
PI - Plasticity Index
GS - Specific Gravity
NAT W, % - % Water



PROJECT								BORING NO.		OAKLAND		SAMPLE NO.		OUTER											
								DEPTH/ELEV		LE		DATE		14 JUN 91											
CLASSIFICATION																									
CLAYEY SAND (SC), GRAY																									
LL		44		PL		19		PI		25		CS		2.74		NAT W. %		58.3		ORG. %					
GRADATION CURVE																LABORATORY USAE WES - STF/QL									



			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE, TSF			WATER CONTENT, %	60.8
PRECONSOL. PRESSURE, TSF			DRY DENSITY, PCF	89.9
COMPRESSION INDEX			SATURATION, %	100 +
TYPE SPECIMEN			VOID RATIO	1.659
DIA. IN	2.50	HT. IN	1.500	BACK PRESSURE, TSF
CLASSIFICATION CLAYEY SAND (SC), GRAY				
LL	44	PL	19	PI 25
PROJECT				
GS	2.74	D ₁₀		
REMARKS:		BORING NO.	OAKLAND	SAMPLE NO.
		DEPTH/ELEV	LE	TECH.
		LABORATORY	USAE WES - STF/GL	DATE
		21 MAY 91		
CONSOLIDATION TEST REPORT				



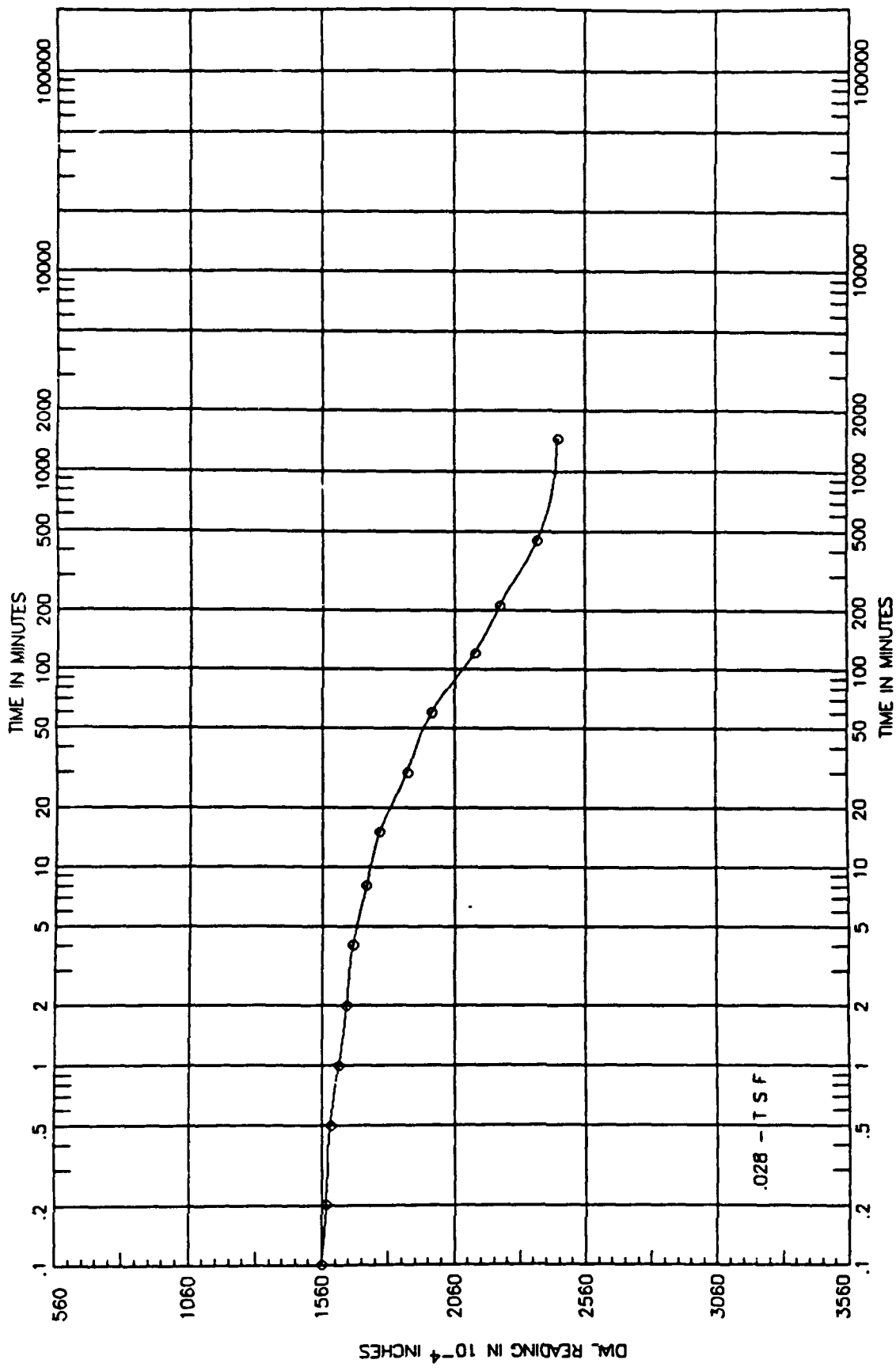
CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT

BORING OAKLAND SAMPLE NO. OUTER

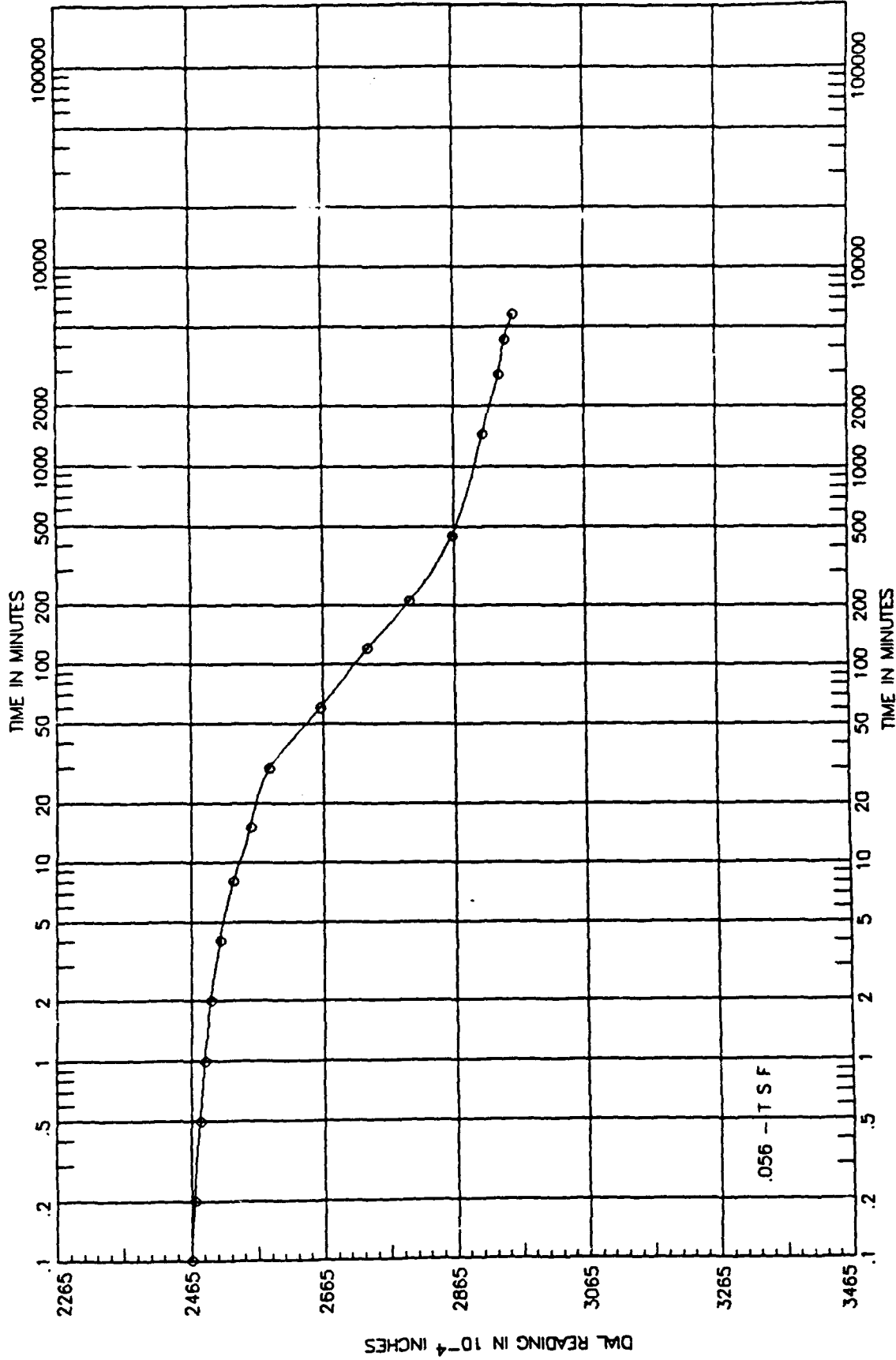
DEPTH/ELEV LE DATE 21 MAY 91



CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT			
BORING	OAKLAND	SAMPLE NO.	OUTER
DEPTH/ELEV	LE	DATE	21 MAY 91



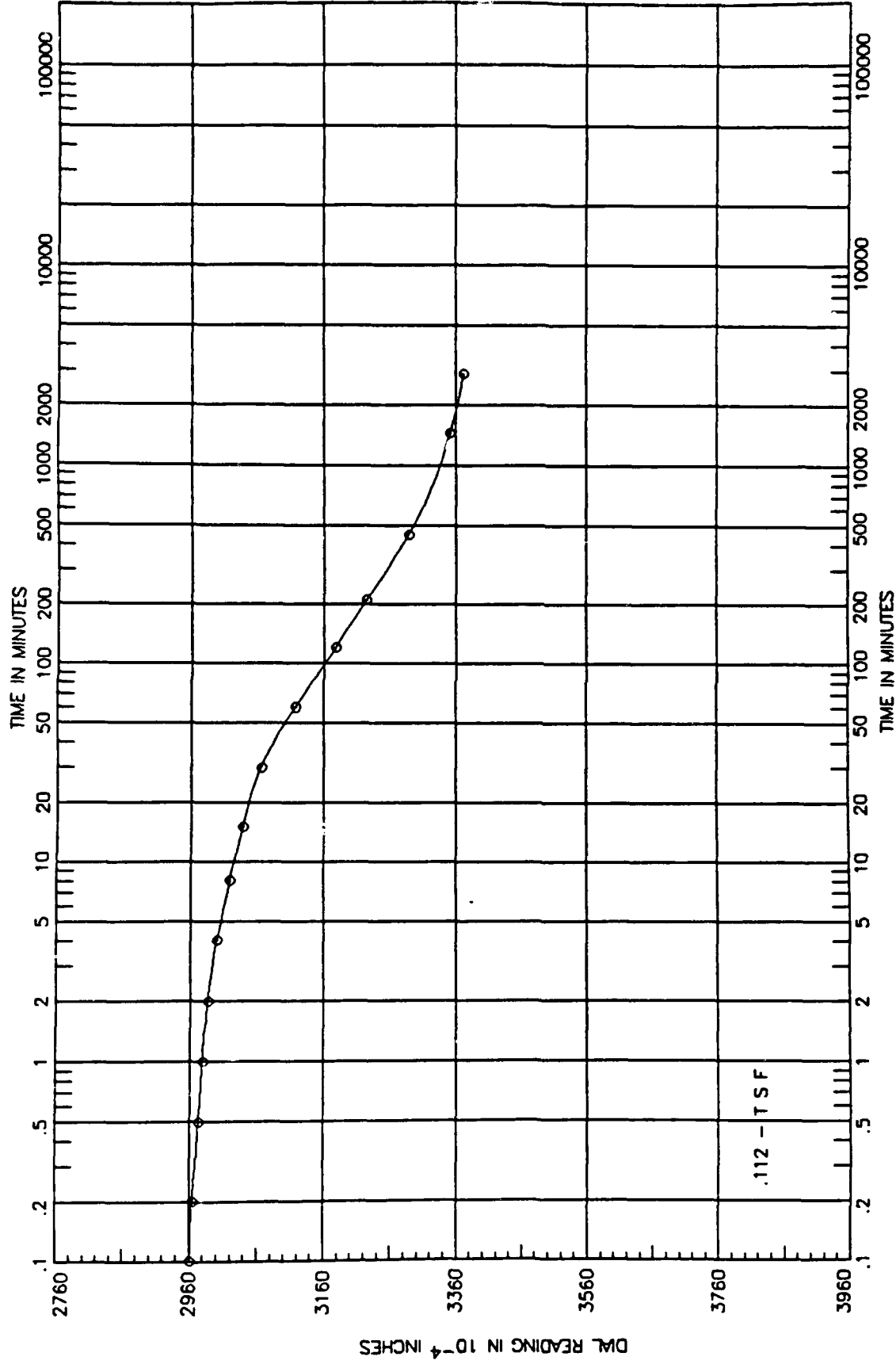
CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT

BORING OAKLAND SAMPLE NO. OUTER

DEPTH/ELEV LE DATE 21 MAY 91



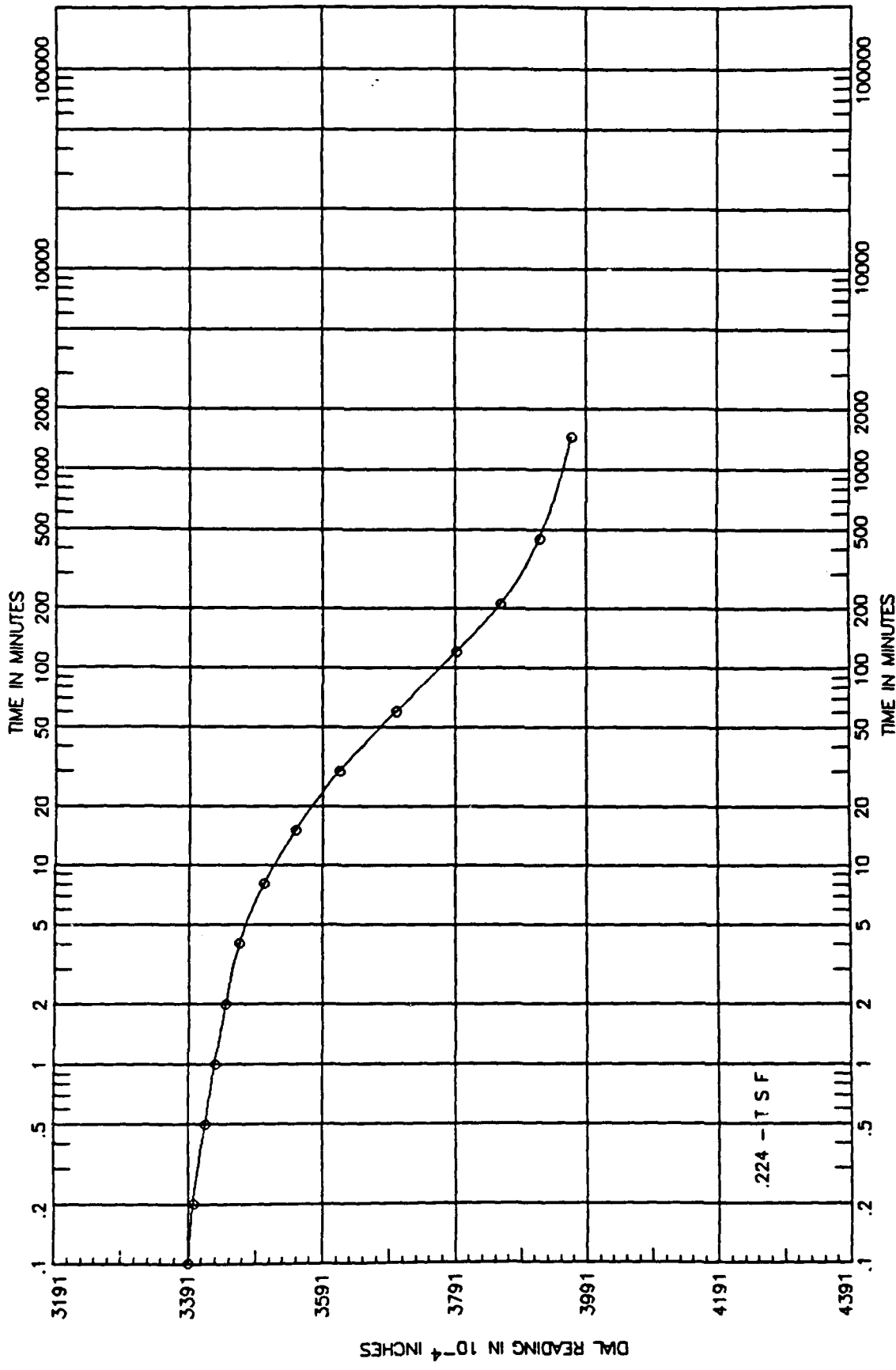
CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT

BORING OAKLAND SAMPLE NO. OUTER

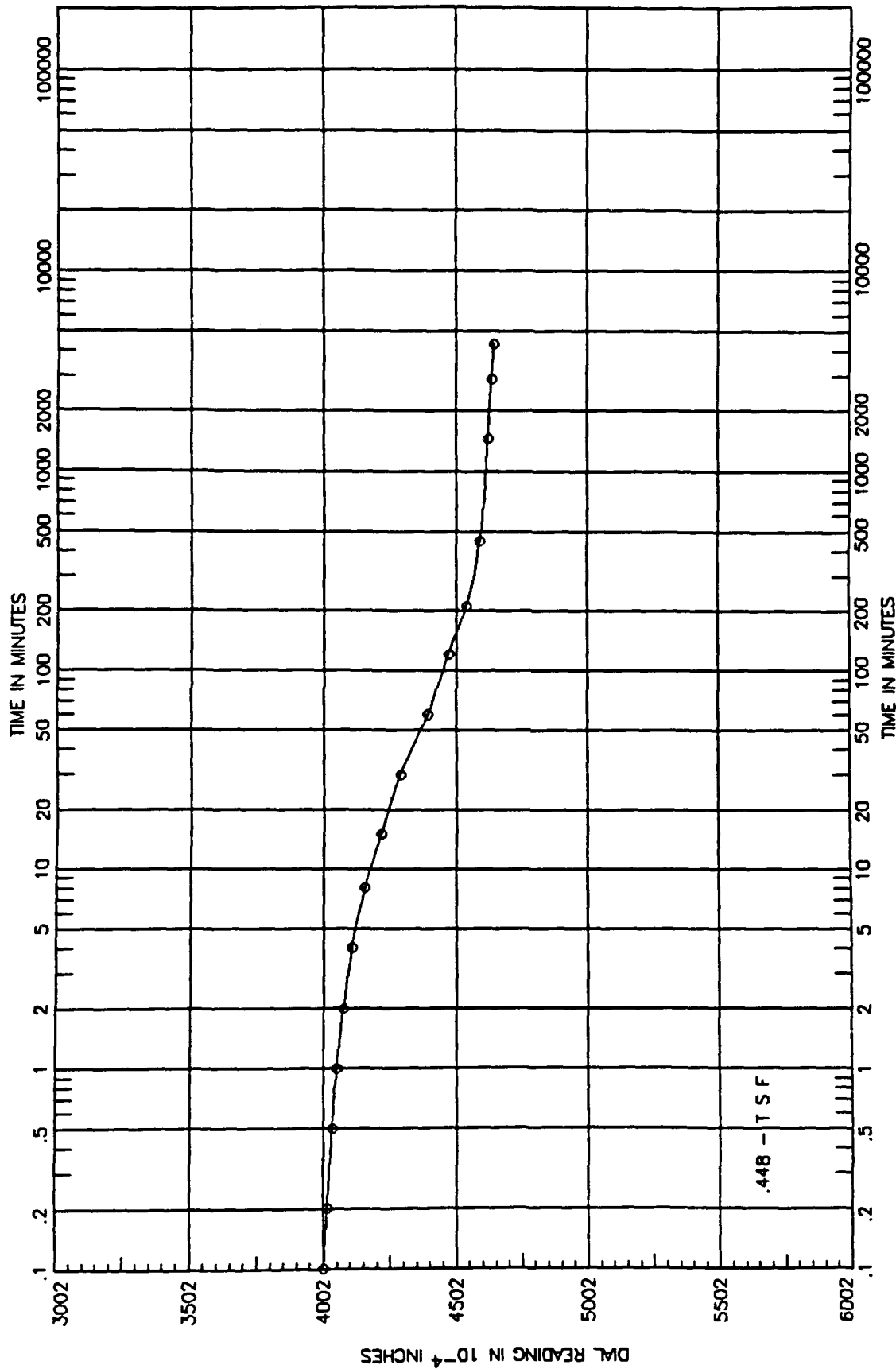
DEPTH/ELEV LE DATE 21 MAY 91



CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT			
BORING	OAKLAND	SAMPLE NO.	OUTER
DEPTH/ELEV	LE	DATE	21 MAY 91



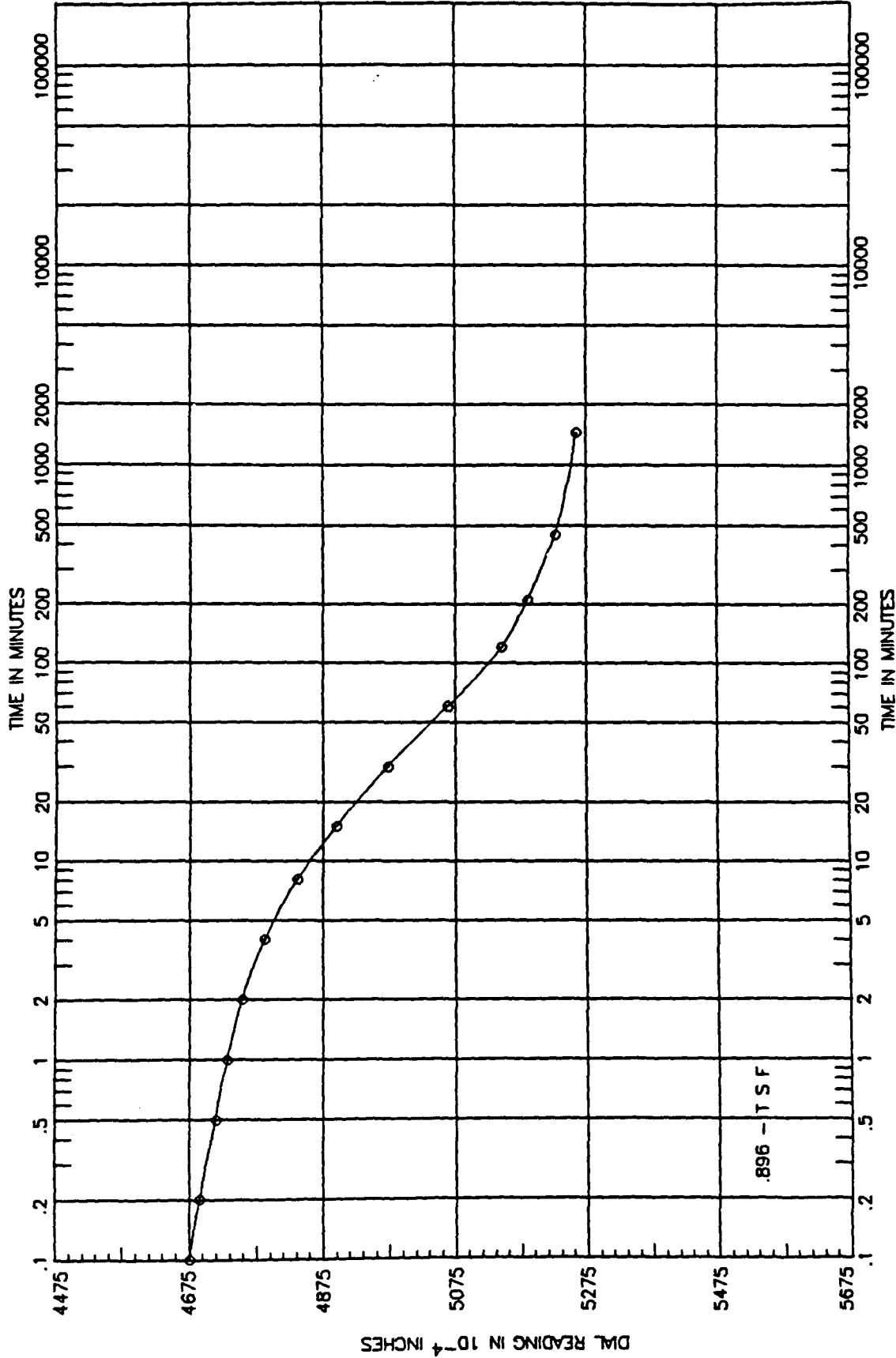
CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT

BORING OAKLAND SAMPLE NO. OUTER

DEPTH/ELEV LE DATE 21 MAY 91



CONSOLIDATION TEST TIME CURVES

LABORATORY USAE WES - STF/GL

PROJECT

BORING OAKLAND SAMPLE NO. OUTER

DEPTH/ELEV LE DATE 21 MAY 91

APPENDIX B: EFFLUENT TEST

KEY

	<u>Sponsor Code</u>	<u>Description</u>
Oakland Inner Sediment Elutriate	OKINE-1-U	Rep 1, Unfiltered
	OKINE-2-U	Rep 2, Unfiltered
	OKINE-3-U	Rep 3, Unfiltered
	OKINE-1-F	Rep 1, Filtered
	OKINE-2-F	Rep 2, Filtered
	OKINE-3-F	Rep 3, Filtered
Oakland Outer Sediment Elutriate	OKOUE-1-U	Rep 1, Unfiltered
	OKOUE-2-U	Rep 2, Unfiltered
	OKOUE-3-U	Rep 3, Unfiltered
	OKOUE-1-F	Rep 1, Filtered
	OKOUE-2-F	Rep 2, Filtered
	OKOUE-2-F	Rep 3, Filtered
	OK-S1-AU	QA/QC Duplicate
	OK-S1-BU	QA/QC Duplicate

WATER DATA

Project: KLANDINNER
Sponsor: TEM

(CF#209)

6/6/91

WATER METAL DATA

(Concentrations in UG/L)

Sample Code	Sponsor Code	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
1% HNO3											
209-13	ACID BLANK										
209-14	OKINE-1-U	0.01	3.82	0.070	1.30	3.72	0.057	4.42	2.75	< 3.09	29.80
209-15 #1	OKINE-2-U	0.03	4.24	0.088	0.86	3.79	0.023	5.78	1.46	< 3.09	14.90
209-16	OKINE-3-U	0.01	2.12	0.084	2.03	2.58	0.016	4.30	2.11	< 3.09	24.70
209-17	OKINE-1-F	0.01	3.82	0.082	0.40	3.49	0.021	4.08	1.41	< 3.09	16.30
209-18	OKINE-2-F	0.05	2.97	0.370	0.94	6.94	0.075	4.47	6.14	< 3.09	52.20
209-19	OKINE-3-F	0.02	2.55	0.200	1.03	3.51	0.026	5.44	3.10	< 3.09	34.70

- All metals re-analyzed by AA.

.. Hg analyzed by CVAA.

STANDARD REFERENCE MATERIAL

CASS-2

CERTIFIED VALUES:

2

< 1.27

1.01

0.027

0.019

0.13

0.127

NA

3

0.303

0.298

NA

2

SLAS

CERTIFIED VALUES:

2

0.019

0.015

0.36

0.38

0.900

1.070

NA Indicates not analyzed

NC indicates not certified

2.57
-76.47
1.97
+ .12

WATER DATA

Project: OAKLAND INNER
Sponsor: TATEM

(CF#209)

2/7/91

WATER BUTYLtin RESULTS

(Concentrations in ng/L; ppt)

Sample Code	Sponsor Code	TETRA-BUTYLtin	TRI-BUTYLtin	DI-BUTYLtin	MONO-BUTYLtin	% Surrogate Recovery PROPYLtin
OKINE-4-U	10-Oct	10.7	3.3	12.0	13.00	48%
OKINE-4-F	11-Oct	< 20.8	61.4	39.1	< 13.3	NS
OKINE-8-U	10-Oct	< 2	52.4	17.0	12.70	34%
OKINE-8-F	10-Oct	4.1	62.6	19.6	12.90	24%
OKINE-8-F DUPI	11-Oct	< 25	59.3	32.0	< 22.6	31%
OKINE-9-U	10-Oct	< 2.6	66.7	74.2	25.4	34%
OKINE-9-F	11-Oct	< 19.9	59.6	< 18.8	23.00	66%
METHOD BLANK		< 0.7	6.6	5.8	< 0.6	19%
SPIKE BLANK RECOVERY (SPIKED WITH 100 NG/L)	11-Oct	399.8 100%	465.2 116%	465.2 109%	11.2 2%	75%

209WATER

WATER DATA

Project: OAKLAND INNER
Sponsor: TATEM

(CF#209)

2/7/91

WATER PAH DATA

(Concentrations in ng/L)

Sponsor Code :
Battelle Code :

	OKINE-4-F	OKINE-4-U	OKINE-6-U	OKINE-7-U	OKINE-8-F	OKINE-8-U	OKINE-9-U	BLANK	SPIKE BLANK (spiked with 100 ng/L)	SPIKE RECOVERIES
NAPHTHALENE	13.1 X	13 X	26.4	9.1	1 U	12.5	6.7 X	1 U	21.8	22%
ACENAPHTHYLENE	1 U	1 U	7.5 U	1 U	1 U	1 U	1 U	1 U	20.8	21%
ACENAPHTHENE	1 U	1 U	5.6 U	1 U	1 U	5.3 X	1 U	1 U	20.8	21%
FLUORENE	1 U	1 U	7.5 U	1 U	1 U	1 U	6.1 X	1 U	22.1	22%
PHENANTHRENE	1 U	1 U	9.2 U	2.8 X	1 U	4.7 X	1 U	4.9 X	24.3	24%
ANTHRACENE	65.8 E	1 U	8.7 U	1 U	4.9	1 U	1 U	1 U	23.1	23%
FLUORANTHENE	25.1 X	5.4 X	6.7 X	4.1 X	2.1	6.3 X	3.5 X	4.3 X	47.2	47%
PYRENE	59.6 E	19 X	30.5	19	2.4	33.3	3.7 X	8.4 X	50.6	51%
BENZ[ANTHRACENE]	1 U	3.7 X	10.6 U	2.3 X	1 U	1 U	1 U	20.8 E	107.8	108%
CHRYSENE	1 U	5.6 X	9.7 U	1 U	1 U	3.6 X	1 U	1 U	97	97%
BENZO[KL]FLUORANTHENE	1 U	5.8	14.2 U	1 U	1 U	6.5	1 U	5.3 E	97.3	97%
BENZO[APYRENE]	37.1 E	10.2 X	15.2 U	2.6	1 U	3.7 X	4.3	5.3 X	121.9	122%
INDENO[1,2,3-cd]PYRENE	1 U	12.7	18.8 U	2.7 X	1 U	6.4	1 U	6.2 E	119.5	120%
DIBENZ[AN]ANTHRACENE	1 U	12.7 X	25.6 U	2.5 X	1 U	5.7	1 U	1 U	156.2	156%
BENZO[ghi]PERYLENE	1 U	1 U	15.7 U	1 U	1 U	1 U	1 U	1 U	118.2	118%
	16 X	17	51.8 U	3.7 X	1 U	7.5	1 U	8.9 E	133	133%
SURROGATE RECOVERY:										
D8-NAPHTHALENE	38%	14%	62%	13%	14%	25%	20%	4%	23%	
D10-ACENAPHTHALENE	106%	15%	64%	16%	13%	27%	44%	20%	27%	
D10-PHENANTHRENE	460%	16%	N/A	23%	78%	34%	104%	71%	31%	
D12-PERYLENE	401%	180%	129%	183%	175%	205%	284%	728%	163%	

U Indicates analyte not detected at or above detection limit shown

X Indicates no confirmation ion found

E Indicates values are estimates due to excessively high corresponding surrogate recoveries.

241WATER

WATER DATA

Project: OAKLAND OUTER
Sponsor: TATEM

(CF#241)

6/7/91

WATER METAL DATA

(Concentrations in UG/L)

Battelle Code	Sponsor Code	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
241-01	OKOUE-1-U	0.02	1.91 U	0.26	1.77	3.97	0.016	5.21	2.38	3.09 U	25.6
241-02	OKOUE-2-U	0.03	1.91	0.31	1.68	4.75	0.014	5.90	2.19	3.09 U	26.5
241-03	OKOUE-3-U	0.03	4.46	0.31	1.93	5.46	0.016	6.01	2.51	3.09 U	50.2
241-04	OKOUE-1-F	0.01	3.18	0.31	0.52	31.6	0.009	4.36	3.34	3.09 U	46.7
241-05	OKOUE-2-F	0.01	4.46	0.27	0.31	29.8	0.006	4.08	2.70	3.09 U	44.3
241-06	OKOUE-3-F	0.01	1.91 U	0.28	0.52	39.4	0.005	4.19	2.91	3.09 U	46.7
241-19	OKSI-A-U	0.02	2.55	0.54	0.52	7.21	0.008	2.65	1.92	3.09 U	26.2
241-20	OKSI-B-U	0.02	1.91 U	0.6	0.52	8.88	0.007	2.60	2.19	3.09 U	26.5

STANDARD REFERENCE MATERIAL

1641

CERTIFIED VALUES:

1.46
1.52
±0.04

CASS-2

CERTIFIED VALUES:

0.01 U
NC

0.303
0.298
±0.36

0.033 U
0.019
±0.006

NA
NC
±0.12

SLRS-1

0.01 U
NC

0.900
1.070
±0.06

0.101
0.106
±0.011

NA
NC
NA

* Detection limits elevated due to saltwater interferences.

U indicates not detected at detection limit shown

NA indicates not analyzed

NC indicates not certified

241WATER

WATER DATA

Project: OAKLAND OUTER
Sponsor: TATEM

(CF#241)

3/22/91

WATER PAH DATA

(Concentrations in ng/L)

Sponsor Code OKOUE-7-U
Battelle Code: 241-13

	OKOUE-7-U 241-13	OKOUE-8-U 241-14	OKOUE-6-U 241-9	OKOUE-4-F 241-10	OKOUE-3-F 241-17	OKOUE-2-F 241-18	OKSI-A 241-19	OKSI-B 241-20	METHOD BLANK
NAPHTHALENE	49.3 U	154.5 U	26.3 U	28.2 U	273.2 U	47.2 U	35.7 U	93.5 U	47.6 U
ACENAPHTHYLENE	7.5 U	23.5 U	4 U	4 U	41.5 U	7.2 U	5.4 U	14.2 U	7.2 U
ACENAPHTHENE	18.7 U	58.7 U	10 U	10 U	103.7 U	17.9 U	13.6 U	35.5 U	18 U
FLUORENE	15 U	46.9 U	8 U	8 U	83 U	14.4 U	10.9 U	28.4 U	14.5 U
PHENANTHRENE	20 U	65.6 U	11.7 U	10.6 U	110.6 U	19.1 U	14.5 U	37.9 U	19.3 U
ANTHRACENE	8.7 U	27.4 U	4.7 U	4.7 U	48.4 U	8.4 U	6.3 U	16.6 U	8.43 U
FLUORANTHENE	12.5 U	39.1 U	6.7 U	6.6 U	69.1 U	12 U	9.1 U	23.7 U	12 U
PYRENE	15.3	29.8	5 U	5 U	51.9 U	9.1	6.8 U	17.8 U	9 U
BENZANTHRACENE	8.7 U	27.4 U	4.7 U	4.7 U	48.4 U	8.4 U	6.3 U	16.6 U	8.4 U
CHRYSENE	7.5 U	23.5 U	4 U	4 U	41.5 U	7.2 U	5.4 U	14.2 U	7.2 U
BENZO [B,K] FLUORANTHENE *	9.4 U	29.3 U	5 U	5 U	51.9 U	9 U	6.8 U	17.8 U	9 U
BENZO [A] PYRENE	7.5 U	23.5 U	4 U	4 U	41.5 U	7.2 U	5.4 U	14.2 U	7.2 U
INDENO [1,2,3-cd] PYRENE	11.8 U	37.2 U	6.3 U	6.3 U	65.7 U	11.4 U	8.6 U	22.5 U	11.5 U
DIBENZ [a,h] ANTHRACENE	6.9 U	21.5 U	3.7 U	3.7 U	38 U	6.6 U	5 U	13 U	6.6 U
BENZO [ghi] PERYLENE	6 U	18.8 U	3.2 U	3.2 U	33 U	5.7 U	4.3 U	11.6 U	5.8 U
SURROGATE RECOVERY:									
D10-FLUORENE	77%	76%	33%	46%	77%	62%	78%	80%	78%
D10-ANTHRACENE	80%	79%	34%	54%	78%	67%	82%	82%	76%
D10-PYRENE	80%	86%	36%	58%	84%	82%	84%	83%	78%

U Indicates analyte not detected at or above detection limit shown
* All benzofluoranthene isomers are quantified together

WATER DATA
Project:
Sponsor:

OAKLAND OUTER
TATEM

(CF#241)

3/22/91

WATER BUTYLtin RESULTS

(Concentrations in ng/L; ppb)							% Surrogate Recovery PROPYLTIN
Sample Code	Sponsor Code	TETRA- BUTYLtin	TRI- BUTYLtin	DI- BUTYLtin	MONO- BUTYLtin		
241-13	OKOUE- 7-U	2.2 U	10.2 B	4.5 B	2.6		56%
241-14	OKOUE- 8-U	1.7 U	11.1 B	3.0 B	1.4 U		42%
241-15	OKOUE- 9-U	1.9 U	10.8 B	12.7 B	2.7		46%
241-16	OKOUE- 7-F	1.3 U	10.6 B	37.4 B	14.3		50%
241-17	OKOUE- 8-F	2.0 U	8.7 B	22.2 B	7.6		41%
241-18	OKOUE- 9-F	2.1 U	12.9 B	39.2 B	11.9		54%
241-19	OKSI- A-U	1.0 U	6.8 B	2.8 B	0.9 U		60%
241-20	OKSI- B-U	0.8 U	6.5 B	0.8 U	0.7 U		47%
METHOD BLANK		1.0 U	5.1 B	1.2	0.9 U		46%

AMOUNT RECOVERED:

59

73

46

30

43%

PERCENT RECOVERY:

59%

73%

45%

30%

43%

N/A Indicates data not available. Due to contamination of initial sample, no sample was left for re-analyses.
U Indicates not detected at detection limit shown.

B Indicates analyte detected in method blank

APPENDIX C: SURFACE RUNOFF DATA

Surface Runoff Test

KEY

	<u>Sponsor Code</u>	<u>Description</u>
Oakland Outer Wet Sediment	OOW-1-METU	Rep 1, Metals, Unfiltered
	OOW-1-METF	Rep 1, Metals, Filtered
	OOW-2-METU	Rep 2, Metals, Unfiltered
	OOW-2-METF	Rep 2, Metals, Filtered
	OOW-2-METF2	Rep 2, Metals, Unfiltered, Duplicate
	OOW-3-METU1	Rep 3, Metals, Unfiltered
Oakland Inner Wet Sediment	OOW-3-METF1	Rep 3, Metals, Filtered
	OOW-3-METU3	Rep 3, Metals, Unfiltered, Method Blank
	OIW-1-METU	Rep 1, Metals, Unfiltered
	OIW-1-METF	Rep 1, Metals, Filtered
	OIW-2-METU	Rep 2, Metals, Unfiltered
	OIW-2-METF	Rep 2, Metals, Filtered
Oakland Outer Dry Sediment	OIW-3-METF2	Rep 3, Metals, Unfiltered, Duplicate
	OIW-2-METU3	Rep 2, Metals, Unfiltered, Method Blank
	OOD-1-MET-RO	Rep 1, Metals, Reverse Osmosis Purified Water
Oakland Inner Dry Sediment	OOD-1-PAHU	Rep 1, PAHs, Unfiltered
	OLD-1-MET-RO	Rep 1, Metals, Reverse Osmosis Purified Water
	OLD-1-PAHU	Rep 1, PAHs, Unfiltered

SAMPLE LABEL KEY

First Letter: O = Oakland Project

Second Letter: I = Inner*, O = Outer

Third Letter: W = wet, unoxidized sediment, D = dry, oxidized sediment

First Number = replicate number

MET = sample analyzed for heavy metals

TBT = sample analyzed for organo tins

PAH = sample analyzed for PAHs and organo tins

U or F = unfiltered or filtered sample, RO = rain water sample for dry oxidized tests

Second Number: 1 and 2 = duplicates of each other, 3 = rain water sample for wet, unoxidized tests

Example: OIW-3-METU2

Oakland project

Inner sediment

Wet, unoxidized sediment

Replicate 3

Sample analyzed for heavy metals

Unfiltered sample

Duplicate number 2

* I was transcribed by the analytical laboratory as an L for samples from the dry, oxidized sediment

206WATER

WATER DATA

Project: OAKLAND INNER/OUTER
Sponsor: SKOGERBOE

(CF#206)

6/6/91

WATER METAL DATA

(Concentrations in UG/L)

Sample Code	Sponsor Code	Ag	As	Cd	Cf	Cu	Hg	Ni	Pb	Se	Zn
1% HNO3	ACID BLANK	0.17	0.0	0.2	0.8	2.1	0.0012	2.0	0.4	-0.1	2.6
206-8	OOW-1-METU	0.48	52.3	5.4	60.7	238.5	0.0012	206.0	83.6	7.8	670.0
206-9	OOW-1-METF	0.25	63.5	0.2	2.4	5.1	0.0012	2.6	0.9	4.8	33.7
206-10	OIW-3-METU2	0.13	10.2	17.3	77.2	125.5	0.0013	201.0	38.2	5.0	287.0
206-11	OIW-3-METF	0.12	10.0	0.3	2.0	6.0	< 0.0004	2.0	0.7	0.4	11.0
206-12	OIW-3-METU	0.12	0.4	0.3	0.6	5.8	< 0.0004	0.6	0.3	2.9	5.7
206-13	OIW-3-METU3	0.13	12.9	5.1	76.6	118.1	0.0014	196.0	39.8	3.9	278.0
206-14	OIW-3-METF2	0.09	13.8	1.9	3.4	5.6	< 0.0004	5.3	0.9	0.0	19.0
206-15	OIW-2-METF	0.25	18.3	0.7	2.6	3.8	< 0.0004	2.8	0.3	0.3	11.0
206-16	OIW-2-METU3	0.10	0.5	0.2	0.8	5.4	0.0005	0.7	0.2	2.6	4.2
206-17	OIW-2-METU	0.12	16.8	5.9	70.6	133.3	0.0044	201.0	39.3	2.6	316.0
206-18	OIW-1-METF	0.13	23.9	0.7	2.7	6.3	< 0.0004	2.6	2.5	1.3	12.0
206-19	OIW-1-METU	0.11	26.6	21.6	136.3	199.1	0.0002	328.0	61.7	6.4	495.0
206-20	OOW-2-METF	0.29	33.4	0.2	2.5	5.3	0.0007	2.4	0.3	1.1	13.0
206-21	OOW-2-METU	0.36	42.6	3.9	83.2	212.9	0.0008	202.0	84.6	5.0	545.0
206-22	OOW-2-METU3	0.14	1.3	0.1	0.6	6.3	< 0.0004	0.5	1.1	1.3	6.6
206-23	OOW-3-METU2						0.0002				
206-24	OOW-3-METF1	0.13	27.7	0.2	1.8	6.4	< 0.0004	1.9	1.7	1.7	15.4
206-25	OOW-3-METU1	0.19	28.5	3.0	82.1	155.6	0.0009	172.2	75.6	3.6	399.9
206-26 #1	OOW-3-METF2	0.13	30.1	0.3	1.8	5.6	0.0006	1.5	0.5	1.3	9.9
206-26 #2	OOW-3-METF2	0.18	30.0	0.3	1.8	5.0	NA	1.7	0.3	3.1	9.4
206-26 #3	OOW-3-METF2	0.11	30.9	0.3	1.9	5.2	NA	1.7	0.2	3.4	10.1

* As values may be high du to Cf+ interferences.

** Hg re-Analyzed by CVAA.

NA Indicates not analyzed

206WATER

WATER DATA
Project: OAKLAND INNER/OUTER
Sponsor: SKOGERBOE

(CF#206) 6/6/91

STANDARD REFERENCE MATERIAL

1643b	11.30	57.5	20.8	18.7	22.3	NA	49.3	25.0	10.2	65.0
1643b	11.89	67.9	20.9	19.6	23.2	NA	54.3	26.3	8.9	66.8
1643b	9.80	~ 49	20.0	18.6	21.9	NC	49.0	23.7	9.7	66.0

CERTIFIED VALUES:
NC indicates not certified

MATRIX SPIKES

Sample Spiked:	Amount Spiked :	Amount Recovered:	Percent Recovery:
OOW-3-METF2	0.14	30.3	0.3
	2.00	10.0	10.0
	2.93	41.3	11.2
	139%	110%	109%
OOW-3-METF2	0.14	30.3	0.3
	25.00	50.0	50.0
	26.50	82.8	52.1
	105%	105%	104%

206WATER

WATER DATA
Project: OAKLAND INNER/OUTER
Sponsor: SKOGERBOE

(CF#206)

2/7/91

WATER BUTYLtin RESULTS

(Concentrations in ng/L; ppt)					% Surrogate Recovery	
Sample Code	Sponsor Code	TETRA-BUTYLtin	TRI-BUTYLtin	DI-BUTYLtin	MONO-BUTYLtin	PROPYLTin
OIW-2-TBTU1	10-Oct	< 2.7	35.80	26.60	67.20	39%
OIW-2-TBTF1	18-Oct	< 0.7	6.00	6.10	1.30	41%
OIW-2-TBTU2	10-Oct	< 3.5	66.70	12.50	4.70	70%
OIW-2-TBTF2	18-Oct	< 1.5	9.70	12.00	1.30	42%
OIW-2-TBTU3		N/A	N/A	N/A	N/A	N/A
OOW-3-TBTU	10-Oct	< 1.7	69.70	10.60	2.40	NS
OOW-3-TBTF	18-Oct	< 1.5	12.80	4.50	< 1.4	48%
OOW-2-TBTU1	18-Oct	< 1.1	9.00	9.10	1.50	42%
OOW-2-TBTF1	18-Oct	< 0.9	8.60	5.70	< 0.8	38%
OOW-2-TBTU2	18-Oct	< 2.8	29.80	52.90	< 2.5	45%
OOW-2-TBTF2	18-Oct	< 1.4	9.80	22.10	3.40	40%
OOW-2-TBTU3	10-Oct	< 1.1	9.20	6.80	10.60	31%
OIW-1-TBTU	10-Oct	< 3.4	58.1	12.1	3.2	68%
OIW-1-TBTF	10-Oct	< 1.9	17.3	32.9	3.6	37%
OIW-3-TBTU	10-Oct	< 3.5	66.5	22.6	5	58%
OIW-3-TBTF	18-Oct	< 1.1	9.1	9.9	2.7	52%
OIW-3-TBTU3	10-Oct	< 1.9	57.2	8.2	5.4	38%
OOW-1-TBTU		N/A	N/A	N/A	N/A	N/A
OOW-1-TBTF	18-Oct	< 0.7	6.6	5.3	0.8	42%
METHOD BLANK		< 0.7	6.6	5.8	< 0.6	19%
SPIKE BLANK RECOVERY (SPIKED WITH 100 NG/L)	11-Oct	399.8 100%	465.2 116%	465.2 109%	11.2 2%	75%

N/A Indicates data not available for these samples.
NS Indicates not spiked with surrogate

331 METALS.DATA

8/20/91

OAKLAND INNER (SKOGERBOE) (CF#331)

WATER METAL RESULTS

(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As ICP-MS	Se ICP-MS	Ag ICP-MS	Cd ICP-MS	Hg CVAA	Pb ICP-MS
331-3 REP 1	OLD-1-MET-U	48.4	135.0	117.0	209.0	4.1		1.57	3.71	0.0662	28.0
331-3 REP 2	OLD-1-MET U	55.5	152.0	133.0	240.0	6.8		1.55	4.01	0.0647	28.6
331-4	OLD-1-MET F	1.3	4.1	4.3	39.5	6.4		1.12	0.75	0.0009 U	0.3
331-5	OLD-1-MET-RO	0.2	7.5	1.4	1.1	1.1		0.99	0.02	0.0112	0.1
331-8	OLD-2-MET-U	16.3	107.0	91.5	166.0	3.3		1.09	1.72	0.0009 U	14.3
331-9	OLD-2-MET-U	1.6	3.7	4.8	30.9	3.7		0.98	0.39	0.0010	0.4
331-10	OLD-2-MET-RO									0.0009 U	
331-15	OLD-3-MET-U	19.7	101.0	85.2	149.0	3.4		1.22	1.62	0.0031	13.2
331-16	OLD-3-MET-F	1.9	17.7	3.6	107.0	0.4		1.02	0.33	0.0009 U	0.5
331-18	OLD-3-MET-RO	0.2	0.5	1.3	1.5	0.4		0.71	0.12	0.0009 U	0.1

U = Indicates not above detection limit.

331 METALS.DATA

8/20/91

OAKLAND INNER (SKOGERBOE) (CF#331)

WATER METAL RESULTS

(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
		ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	CVAA	ICP-MS

STANDARD REFERENCE MATERIAL

1643b REP 1		20.4	48.4	22.6	66.0	50.2		9.8	19.6	NA	22.7
(SRM 1)	certified	18.6	49.0	21.9	66.0	NC		9.8	20	NA	23.7
	value	±0.4	±3	±0.4	±2	NC		±0.8	±1	NA	±0.7
1641b		NA	NA	NA	NA	NA		NA	NA	1.46	NA
	certified	NA	NA	NA	NA	NA		NA	NA	1.52	NA
	value	NA	NA	NA	NA	NA		NA	NA	±0.04	NA

NA = Not applicable

NC = Not certified.

MATRIX SPIKE RESULTS

Amount Spiked	20	20	20	20	20	20	20	100	1	33.3	5.0
331-9 + spike	20	19.6	21.8	104	28.7	39.8	1.41	32.75	4.7		
331-9	1.6	3.7	4.8	30.9	3.7	0.98	0.39	1.03	0.4		
Amount Recovered	18.4	15.9	17.0	73.1	25.0	38.82	1.02	31.72	4.3		
Percent Recovery	92%	80%	85%	366%	125%	39%	102%	95%	86%		

(CF #331)
 OAKLAND INNER (SKOGERBOE)
**ORGANOTIN ANALYSIS
 OF WATER SAMPLES**

7/19/91

MSL Code	Sponsor Code	(concentrations in ng/L)				
		Tripentyl % Surrogate	Tetra Tin	Tributyl Tin	Dibutyl Tin	Monobutyl Tin
331-1-R	OLD-1-PAHU	96.02	4.6 B	16.7 B	29.6 B	29.6 B
331-2	OLD-1-PAHF	72.06	2.3 B	11.6 B	9.7 B	3.6 B
331-6	OLD-2-PAHU	100.68	2.9 B	11.9 B	4.1 B	6.6 B
331-7	OLD-2-PAHF	91.94	2.6 B	13.8 B	3.5 B	26.5 B
331-11	OLD-3-PAHU	86.50	1.6 B	28.3 B	33.0 B	16.5 B
331-12	OLD-3-PAHU DUP	89.38	2.8 B	23.0 B	19.3 B	4.1 B
331-13	OLD-3-PAHF	75.13	2.5 B	13.3 B	2.7 B	4.8 B
331-14	OLD-3-PAHF DUP	65.71	2.9 B	13.2 B	3.9 B	4.0 B
331-17	OLD-3-RO	66.48	2.1 B	13.2 B	22.4 B	11.1 B

METHOD BLANK RESULTS

331-BLANK	65.71	2.3	15.7	5.6	4.0
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BLANK AND MATRIX SPIKE RECOVERIES

331 BLANK SPIKE	65.28	74.1	106.3	86.9	41.1
% Recovery		35.9%	45.3%	40.6%	18.6%

U indicates analyte not detected at detection limit shown

B indicates analyte detected in method blank associated with that sample

8/24/91

(CF #331)
 OAKLAND INNER (SKOGERBOE)
**PAH CONCENTRATIONS
 IN WATER SAMPLES**
 (concentrations in ug/L)

Client ID	Sponsor Code	Naph- thalene	Acenaph- thylene	Acenaph- thene	Flourene	Phenan- threne	Anthra- cene	Flouran- thene	Pyrene	Benzo(a)- Anthracene
331-1	OLD-1-PAHU	63.7 B	33.1	20.2	23.3	234.8 B	71.7	523.0 B	1063.7 B	176.0
331-2	OLD-1-PAHF	34.6 B	10.0 U	10.0 U	10.0 U	70.4 B	12.8	86.3 B	161.7 B	22.9
331-6	OLD-2-PAHU	48.0 B	18.3	14.8	16.8	140.3 B	44.0	239.1 B	450.8 B	77.8
331-7	OLD-2-PAHF	30.2 B	10.0 U	10.0 U	10.0 U	32.0 B	10.0 U	20.3 B	39.3 B	10.0 U
331-11	OLD-3-PAHU	48.3 B	31.8	11.6	15.6	124.2 B	41.3	333.4 B	664.8 B	130.6
331-12	OLD-3-PAHU DUP	36.9 B	10.0 U	10.0 U	13.6	84.1 B	19.5	127.0 B	266.6 B	41.7
331-13	OLD-3-PAHF	12.1 B	10.0 U	10.0 U	10.0 U	28.9 B	10.0 U	28.6 B	32.2 B	10.0 U
331-14	OLD-3-PAHF DUP	17.6 B	10.0 U	10.1	12.0	77.3 B	13.2	78.8 B	82.1 B	24.4
331-17	OLD-3-RO	18.1 B	10.0 U	10.0 U	10.0 U	26.1 B	10.0 U	65.1 B	43.8 B	20.8
Lab Method Blank		17.4	10.0 U	10.0 U	10.0 U	34.7	10.0 U	14.3	11.3	10.0 U
LAB SPIKE 1		386.3 B	423.5	424.6	433.5	479.7 B	475.4	722.7 B	562.2 B	541.2
LAB SPIKE 1 DUP		354.8 B	408.2	426.0	451.6	488.4 B	505.4	653.5 B	538.1 B	497.1

B = Used when the analyte is found in the associated blank as well as in the sample.
 U = Indicates analyte not detected above the detection limits.

331pah.data

(CF #331)
OAKLAND INNER (SKOGERBOE)
**PAH CONCENTRATIONS
IN WATER SAMPLES**

(concentrations in ug/L)

Client ID	Sponsor Code	% Surrogate Recovery									
		Chrysene	Benzo(b)- Benzo(k)- Flouranthene	Benzo(a)- Pyrene	Indeno- (1,2,3-cd) Pyrene	Dibenz(a,h)- Anthracene	Benzo(ghi)- Perylene	D10 ene	Flour- racene	D10 Anth- rene	Py- rene
331-1	OLD-1-PAHU	178.4	729.5	473.1	365.0	62.5	451.0	80%	96%	91%	
331-2	OLD-1-PAHF	24.7	107.8	56.2	40.1	10.0 U	49.2	81%	89%	87%	
331-6	OLD-2-PAHU	81.8	393.3	276.0	207.8	35.8	279.1	68%	79%	83%	
331-7	OLD-2-PAHF	10.0 U	20.0 U	10.0 U	10.0 U	10.0 U	10.0 U	66%	67%	68%	
331-11	OLD-3-PAHU	152.1	549.6	378.9	301.0	48.1	422.9	67%	82%	78%	
331-12	OLD-3-PAHU DUP	47.2	168.8	91.2	54.8	10.0 U	76.7	70%	77%	73%	
331-13	OLD-3-PAHF	10.0 U	20.0 U	10.0 U	10.0 U	10.0 U	10.0 U	61%	67%	64%	
331-14	OLD-3-PAHF DUP	35.0	54.4	17.4	12.2	10.0 U	13.7	51%	58%	55%	
331-17	OLD-3-RO	29.6	67.3	15.3	11.0	10.0 U	12.0	97%	101%	91%	
Lab Method Blank		10.0 U	20.0 U	10.0 U	10.0 U	10.0 U	10.0 U	77%	86%	88%	
LAB SPIKE I		473.9	1210.0	600.7	661.7	628.1	597.9	80%	89%	92%	
LAB SPIKE I DUP		441.4	1174.5	600.0	685.3	724.1	628.8	85%	95%	97%	

B = Used when the analyte is found in the associated blank as well as in the sample.

U = Indicates analyte not detected above the detection limits.

(CF #331)
 OAKLAND INNER (SKOGERBOE)
PAH CONCENTRATIONS
IN WATER SAMPLES
 (concentrations in ug/L)

8/24/91

331pah.WK1

MATRIX SPIKE RECOVERIES

LAB SPIKE I

Spike Added
 Spike Recovered
 Percent Recovered

LAB SPIKE I DUP

Spike Added
 Spike Recovered
 Percent Recovered

Naph- thalene	Flourene	Anthra- cene	Flour- anthene	Benz[a]- anthracene	Benzo[a]- pyrene	Benzo[ghi]- perylene
500	500	500	500	500	500	500
386	433	475	723	541	601	598
74%	87%	95%	142%	108%	120%	120%
500	500	500	500	500	500	500
355	452	505	654	497	600	629
67%	90%	101%	128%	99%	120%	126%

338 METALS.DATA

8/21/91

OAKLAND OUTER (SKOGERBOE) (CF #338)

WATER METAL RESULTS

(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As ICP-MS	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVAA	Pb ICP-MS
338-11	OOD-1-MET-U	21.0	47.6	59.4	125.0	5.4		1.18	0.88	0.0010	26.2
338-12	OOD-1-MET-F	2.5	5.5	6.4	6.9	5.9		1.06	0.76	0.0051	0.8
338-13 REP 1	OOD-1-MET-RO	0.2	0.5	2.7	2.0	0.4		0.78	0.01	0.0702	0.2
338-13 REP 2	OOD-1-MET-RO	0.2	0.5	2.4	1.3	0.4		0.76	0.01	0.0669	0.2
338-14	OOD-2-MET-U	30.1	54.3	62.0	127.0	5.9		1.20	0.78	0.0010	32.0
338-15	OOD-2-MET-F	1.1	3.0	3.7	4.4	1.5		1.11	0.09	0.0010	0.5
338-16	OOD-2-MET-RO	0.2	0.5	1.1	3.0	0.4		1.10	0.03	0.0002	0.1
338-17	OOD-3-METU-1	32.8	59.8	62.8	132.0	5.6		1.21	0.70	0.0009	34.3
338-18	OOD-3-METU-2	32.7	59.7	62.0	132.0	6.1		1.16	0.68	0.0004	32.9
338-19	OOD-3-METF-1	1.4	2.6	3.6	4.3	0.4		1.09	0.10	0.0003	0.8
338-20	OOD-3-METF-2	1.0	1.9	3.1	3.4	0.5		1.10	0.08	0.0005	0.5
338-21	OOD-3-MET-RO	0.2	0.5	1.5	1.4	0.4		1.17	0.01	0.0001	0.1

338 METALS DATA

8/21/91

OAKLAND OUTER (SKOGERBOE) (CF #338)

WATER METAL RESULTS

(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As ICP-MS	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVAA	Pb ICP-MS
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STANDARD REFERENCE MATERIAL

1643b REP 1 (SRM 2)	certified value	21.5 18.6 ±0.4	46.7 49 ±3	23.2 21.9 ±0.4	63 66 ±2	53 NC NC		9.8 9.8 ±0.8	19.3 20 ±1	NA NA NA	21.3 23.7 ±0.7
1641b	certified value	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	1.46 1.52 ±0.04	NA NA NA

MATRIX SPIKE RESULTS

Amount Spiked	20	20	20	20	20	20	20	100	1	5
338-18+ Spike	64.2	94.2	84.5	157	26.9			35.2	1.85	39.1
338-18	32.7	59.7	62	132	6.1			1.16	0.68	32.9
Amount Recovered	31.5	34.5	22.5	25	20.8			34.04	1.17	6.2
Percent Recovered	158%	173%	113%	125%	104%			34%	117%	124%

NA = Indicates not applicable.
NC = Indicates not certified.

7/22/91

WES OAKLAND OUTER (SKOGERBOE) CF #338))

**ORGANOTIN ANALYSIS
OF WATER SAMPLES**

MSL Code	Sponsor Code	(concentrations in ng/L)				
		100 Triphenyl % Surrogate	Tetra Tin	Tributyl Tin	Dibutyl Tin	Monobutyl Tin
338-1	OOD-1-PAHU	101%	2.5 U	2.8 U	15.3	13.2
338-2	OOD-1-PAHF	143%	2.8 U	3.2 U	2.8 U	8.7
338-3	OOD-1-RO	92%	2.4 U	2.8 U	12.8	11.8
338-4	OOD-2-PAHU	101%	2.3 U	3.0	12.6	12.0
338-5	OOD-2-RO	91%	2.9 U	3.3 U	4.8	6.7
338-6	OOD-3-PAHU-1	93%	1.8 U	2.2	11.4	21.7
338-7	OOD-3-PAHU-2	100%	3.4 U	3.9 U	9.7	13.1
338-8	OOD-3-PAHF-1	109%	3.3 U	3.8 U	3.3 U	3.0 U
338-9	OOD-3-PAHF-2	95%	3.1 U	3.5 U	6.1	2.8 U
338-10	OOD-3-RO	147%	2.2 U	2.6 U	15.2	N/A

METHOD BLANK RESULTS

338-BLANK-1	160%	2.8 U	3.2 U	2.8 U	6.9
338-BLANK-2	85%	1.9 U	2.2 U	7.2	10.8

BLANK AND MATRIX SPIKE RESULTS

91%	47.7	122.4	130.6	63.1
	22%	60%	64%	27%
85%	100.5	101.8	118.2	106.4
	49%	50%	53%	47%

U indicates analyte not detected at detection limit shown
 N/A indicates matrix interference precluded quantitation

338 PAH.DAT

7/24/91

(CF #338)
OAKLAND OUTER (SKOGERBOE)
PAH CONCENTRATIONS
IN WATER SAMPLES

(concentrations in ug/L)

Client ID	Sponsor Code	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Flouranthene	Pyrene	Benzo(a)-Anthracene
338-1	OOD-1-PAHU	28.4 B	11.4 U	11.4 U	11.4 U	19.4 B	11.4 B	45.8	102.2	11.4 U
338-2	OOD-1-PAHF	20.7 B	10.0 U	10.0 U	10.0 U	19.5 B	10.0 U	10.0 U	12.8	10.0 U
338-3	OOD-1-RO	34.0 B	33.3 U	33.3 U	33.3 U	33.3 U	33.3 U	33.3 U	33.3 U	33.3 U
338-4	OOD-2-PAHU	47.3 B	10.0 U	10.0 U	10.0 U	15.6 B	10.0 U	33.7	75.3	10.0 U
338-5	OOD-2-RO	20.1 B	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U
338-6	OOD-3-PAHU-1	110.1 B	21.3 U	21.3 U	33.0	76.1 B	21.3 U	33.7	73.5	21.3 U
338-7	OOD-3-PAHU-2	55.7 B	12.2 U	12.2 U	14.7	35.8 B	12.2 U	17.7	33.4	12.2 U
338-8	OOD-3-PAHF-1	30.9 B	11.1 U	11.1 U	11.1 U	12.9 B	11.1 U	11.1 U	11.1 U	11.1 U
338-9	OOD-3-PAHF-2	80.5 B	25.0 U	25.0 U	30.5	70.2 B	25.0 U	25.0 U	26.0	25.0 U
338-10	OOD-3-RO	40.4 B	17.5 U	17.5 U	17.5 U	38.2 B	17.5 U	17.5 U	17.5 U	17.5 U
Lab Method Blank		30.5 B	10.0 U	10.0 U	10.0 U	13.9	10.0 U	10.0 U	10.0 U	10.0 U

B = Used when the analyte is found in the associated blank as well as in the sample.
U = Indicates analyte not detected above the detection limits.

338 PAH.DATA

(CF #338)
OAKLAND OUTER (SKOGERBOE)
PAH CONCENTRATIONS
IN WATER SAMPLES

(concentrations in ug/L)

Client ID	Sponsor Code	Benzo(b)- Benzo(k)- Chrysene Fluoranthene					Indeno- (1,2,3-cd) Pyrene		Dibenz(a,h)- Anthracene		Benzo(ghi)- Perylene		% Surrogate Recovery			
		11.4 U	10.0 U	33.3 U	10.0 U	10.0 U	13.3	11.4 U	11.4 U	11.4 U	11.7	11.7	D10 ene	Flour- ene	D10 racene	Anth- rene
338-1	OOD-1-PAHU	11.4 U	22.7 U	13.3	11.4 U	11.4 U	11.4 U	11.4 U	11.4 U	11.4 U	11.7	11.7	91.9	107.0	107.0	90.4
338-2	OOD-1-PAHF	10.0 U	20.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	91.6	97.3	97.3	91.0
338-3	OOD-1-RO	33.3 U	66.7 U	33.3 U	33.3 U	33.3 U	33.3 U	33.3 U	33.3 U	33.3 U	33.3 U	33.3 U	91.4	106.2	106.2	88.6
338-4	OOD-2-PAHU	10.0 U	20.0 U	11.4	10.0 U	10.0 U	11.4	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	85.6	86.9	86.9	85.2
338-5	OOD-2-RO	10.0 U	20.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	86.8	90.2	90.2	89.4
338-6	OOD-3-PAHU-1	21.3 U	42.6 U	21.3 U	21.3 U	21.3 U	21.3 U	21.3 U	21.3 U	21.3 U	21.3 U	21.3 U	87.6	90.5	90.5	90.5
338-7	OOD-3-PAHU-2	12.2 U	24.4 U	12.2 U	12.2 U	12.2 U	12.2 U	12.2 U	12.2 U	12.2 U	12.2 U	12.2 U	86.2	86.5	86.5	86.2
338-8	OOD-3-PAHF-1	11.1 U	22.2 U	11.1 U	11.1 U	11.1 U	11.1 U	11.1 U	11.1 U	11.1 U	11.1 U	11.1 U	49.7	57.1	57.1	50.7
338-9	OOD-3-PAHF-2	25.0 U	50.0 U	25.0 U	25.0 U	25.0 U	25.0 U	25.0 U	25.0 U	25.0 U	25.0 U	25.0 U	93.9	96.7	96.7	89.9
338-10	OOD-3-RO	17.5 U	35.1 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	17.5 U	50.2	50.1	50.1	53.1
Lab Method Blank		10.0 U	20.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	81.9	92.7	92.7	78.2

B = Used when the analyte is found in the associated blank as well as in the sample.

U = Indicates analyte not detected above the detection limits.

(CF #338) #####

OAKLAND OUTER (SKOGERBOE)

PAH CONCENTRATIONS

IN WATER SAMPLES

(concentrations in ug/L)

MATRIX SPIKE RECOVERIES

	Naphthalene					Flourene					Anthra-Flour-anthene					Benz[a]-anthracene					Benz[a]-pyrene					Benzo[ghi]-perylene					% Surrogate Recovery			
	1667	1373	80%	1667	1499	90%	1667	1514	91%	1667	1551	93%	1667	1492	90%	1667	1638	98%	1667	1638	98%	1667	1638	98%	1667	1638	98%	1667	1638	98%	D10 Flour-ene	D10 Anth-racene	D10 Py-rene	
338-3 MS																																		
Spike Added	1667			1667			1667			1667			1667			1667			1667			1667			1667			1667			1667			
Spike Recovered	1373			1499			1514			1551			1492			1638			1638			1638			1638			1638			1638			
Percent Recovered	80%			90%			91%			93%			90%			98%			98%			98%			98%			98%			83%	88%	89%	
338-3 MS DUP																																		
Spike Added	1667			1667			1667			1667			1667			1667			1667			1667			1667			1667			1667			
Spike Recovered	1405			1640			1666			1564			1545			1753			1753			1753			1753			1753			1753			
Percent Recovered	82%			98%			100%			94%			93%			105%			105%			105%			105%			105%			89%	95%	88%	

APPENDIX D: LEACHATE TEST

Leachate Test

KEY

Sediment : OI - Oakland Inner
 OO - Oakland Outer

Condition : AN - Anaerobic
 A - Aerobic

Type : S - Sequential Extract
 K - Kinetic Extract

Day : D - 1 through 10. Day 1 through Day 10

Parameter : MET - Metals
 PAH - Petroleum aromatic hydrocarbons
 TBT - Butyltins
 PEST - Pesticides

Preparation : F - Filtered
 U - Unfiltered

Examples:

OIANS-TBT-D1-1 : Oakland Inner, Anaerobic, Sequential, TBTs, Day 1, Rep 1

OOANK-TBT-D1-1 : Oakland Outer, Anaerobic, Kinetic, TBTs, Day 1, Rep 1.

OIAS-M-D1#1 : Oakland Inner, Aerobic, Sequential, Metals, Day 1, Rep 1.

D1-OOAS-#1 PAH: Oakland Outer, Aerobic, Sequential, PAHs, Day 1, Rep 1.

WATER DATA

Project: OAKLAND
Sponsor: BRAINNON/PRICE

(CF#242)

3/4/91

WATER BUTYLIN RESULTS

(Concentrations in ng/L; ppt)

Battelle CODE	Sponsor Code	QC BATCH NO. (2)	TETRA- BUTYLIN	TRI- BUTYLIN	DI- BUTYLIN	MOXO- BUTYLIN	% Surrogate Recovery PROPYLTIN
242-1	OIANS-TBT-D1-1	1	1.8 U	9.2	6.7	1.5 U	50%
242-2	OIANS-TBT-D1-2	1	8.6 U	46.5	46.2	11.9	54%
242-3	OIANS-TBT-D1-3	1	2.5 U	12.2	7.7	2.2 U	52%
242-4	OIANS-TBT-D2-1	1	2.5 U	18.0	94.2	3.8	44%
242-5	OIANS-TBT-D2-2	1	2.0 U	18.8	12.1	1.7 U	52%
242-6	OIANS-TBT-D2-3	1	2.9 U	21.6	26.9	2.5 U	57%
242-7	OIANS-TBT-D3-1	2R	1.6 U	16.1	12.6	1.3 U	25%
242-8	OIANS-TBT-D3-2	1	2.5 U	27.1	99.1	3.4	39%
242-9	OIANS-TBT-D3-3	1	3.1 U	25.2	12.1	3.8	50%
242-10	OIANS-TBT-D4-1	1	2.8 U	20.4	8.0	2.8	51%
242-11	OIANS-TBT-D4-2	1	3.6 U	19.6	21.9	9.9	43%
242-12	OIANS-TBT-D4-3	1	2.9 U	18.2	10.8	4.7	35%
242-13	OIANS-TBT-D5-1	1	3.0 U	17.3	5.3	2.8	42%
242-14	OIANS-TBT-D5-2	1	2.4 U	22.0	15.3	5.8	37%
242-15	OIANS-TBT-D5-3	1	2.7 U	23.6	14.8	4.6	35%
242-16	OIANS-TBT-D6-1	1	1.8 U	16.3	13.0	5.1	46%
242-17	OIANS-TBT-D6-2	1	2.1 U	28.5	13.4	3.9	47%
242-18	OIANS-TBT-D6-3	1R	1.9 U	21.2	8.8	3.4	46%
242-19	OIANS-TBT-BLANK	1R	2.3 U	11.6	50.6	15.1	32%
242-20	OIANS-TBT-D1-1	1R	2.2 U	13.0	2.5	2.2	20%
242-21	OIANS-TBT-D1-2	1R	3.2 U	11.4	4.5	2.8 U	31%
242-22	OIANS-TBT-D1-2 DUPI	1R	2.6 U	19.2	7.1	2.3 U	36%
242-23	OIANS-TBT-D1-3	1R	2.2 U	14.1	4.5	2.8	42%
242-24	OIANS-TBT-D2-1	1R	4.2 U	37.2	3.8 U	3.8 U	72%
242-25	OIANS-TBT-D2-2	1R	2.4 U	28.3	19.2	3.1	47%
242-26	OIANS-TBT-D2-3	1R	9.5 U	49.0	8.6 U	8.5 U	91%
242-27	OIANS-TBT-D3-1	1R	2.3 U	37.8	80.6	2.5	33%
242-28	OIANS-TBT-D3-2	1R	3.1 U	28.7	12.5	16.8	47%
242-29	OIANS-TBT-D3-3	1	3.1 U	19.1	7.5	2.6 U	24%
242-30	OIANS-TBT-D4-1	1	3.2 U	24.3	10.8	4.3	38%
242-31	OIANS-TBT-D4-2	1	2.8 U	24.4	12.5	3.6	33%
242-32	OIANS-TBT-D4-3 (1)	3R	1.7 U	35.4	19.5	3.9	31%
242-33	OIANS-TBT-D5-1	2	2.4 U	14.9	6.5	105.2 E	13%
242-34	OIANS-TBT-D5-2	2	2.0 U	13.8	7.1	97.2 E	26%
242-35	OIANS-TBT-D5-2 (1)	3R	1.1 U	15.3	6.4	3.0	14%
242-36	OIANS-TBT-D5-3	2	2.2 U	17.3	11.9	130.0 E	10%

WATER DATA

Project: OAKLAND
Sponsor: BRANNON/PRICE
WATER BUTYL TIN RESULTS

(CF#242)

3/4/91

Battelle CODE	Sponsor Code	QC BATCH NO. (2)	(Concentrations in ng/L; ppb)				% Surrogate Recovery PROPYLTIN
			TETRA- BUTYL TIN	TRI- BUTYL TIN	DI- BUTYL TIN	MONO- BUTYL TIN	
242-34	OOANS-TBT-D5-3 (1)	3R	2.3 U	19.9	10.9	3.6	3%
242-35	OOANS-TBT-D6-1	2	2.3 U	17.0	12.7	141.1 E	13%
242-35	OOANS-TBT-D6-1 (1)	3R	2.3 U	16.3	9.5	3.7	13%
242-36	OOANS-TBT-D6-2	2	2.0 U	20.8	11.9	163.6 E	8%
242-36	OOANS-TBT-D6-2 (1)	3R	1.1 U	18.3	13.8	4.1	8%
242-37	OOANS-TBT-D6-3	2	2.4 U	23.7	13.3	118.4 E	19%
242-37	OOANS-TBT-D6-3 (1)	3R	2.7 U	19.5	18.7	15.7	24%
242-38	OOANS-TBT-BLANK	3R	2.7 U	32.1	12.7	10.2	66%
242-39	OIAK-TBT-D1-1	2	2.9 U	15.2	7.2	111.0 E	19%
242-39	OIAK-TBT-D1-1 DUPI	2	2.4 U	15.2	4.6	106.1 E	28%
242-40	OIAK-TBT-D1-2	3R	3.3	20.5	9.2	4.4	66%
242-41	OIAK-TBT-D1-3	3R	2.1 U	16.9	8.3	3.3	55%
242-42	OIAK-TBT-D2-1	3R	2.6 U	20.4	19.3	9.5	60%
242-43	OIAK-TBT-D2-2	3R	1.4 U	17.4	2.9	2.5	53%
242-44	OIAK-TBT-D2-3	3R	1.4 U	18.4	5.4	2.9	53%
242-45	OIAK-TBT-D7-1	3R	1.8 U	16.4	4.7	6.6	53%
242-46	OIAK-TBT-D7-2	3R	1.9 U	19.5	4.4	2.8	57%
242-47	OIAK-TBT-D7-3	2R	2.5 U	10.0	3.7	2.3 U	39%
242-48	OIAK-TBT-BLANK	2	2.0 U	23.4	82.0	7.2	25%
242-49	OOANK-TBT-D1-1	2R	2.8 U	17.5	4.9	2.6 U	45%
242-50	OOANK-TBT-D1-3	2R	2.9 U	11.0	6.8	2.7 U	42%
242-51	OOANK-TBT-D2-1	3	2.7 U	13.3	3.2	3.2	13%
242-51	OOANK-TBT-D2-1 (1)	4R	1.9 U	13.2	3.5	1.8 U	27%
242-52	OOANK-TBT-D2-2	2R	2.4 U	11.7	3.3	2.3 U	41%
242-53	OOANK-TBT-D2-3	2R	2.4	13.9	4.4	2.5	53%
242-54	OOANK-TBT-D7-1	4R	3.2 U	3.7 U	3.1 U	3.0 U	55%
242-55	OOANK-TBT-D7-2	4R	1.7 U	3.7	2.1	1.6 U	73%
242-56	OOANK-TBT-D7-3	4R	2.5 U	2.9 U	12.5	16.6	51%
242-57	OOANK-TBT-BLANK	4R	1.7 U	3.6	3.2	1.5 U	65%

(1) Samples re-extracted due to low initial surrogate recoveries. Both values shown

(2) QC batch identifies which method blank is associated with a particular sample (see Quality Control Data)

U indicates no analyte detected above detection limit shown

E indicates value is suspect. Contamination of sample is likely based on the results of the method blank associated with these samples (blank-2, see quality control data)

242WATER

WATER DATA

Project: OAKLAND
Sponsor: BRANNON/PRICE

(CF#242)

3/4/91

BUTYLtin QUALITY CONTROL DATA

Battelle CODE	Sponsor Code	OC BATCH NO.	TETRA- BUTYLtin	TRI- BUTYLtin	DI- BUTYLtin	MONO- BUTYLtin	Recovery PROPYLtin
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METHOD BLANKS

242-BLK1	1	2.3 U	9.8	11.6	1.9 U	30%
242-BLK2	2	3.0 U	15.9	4.0	215.1	22%
242-BLK3	3	3.2 U	14.7	3.0 U	7.5	9%
242-BLK-1R	1R	1.6 U	12.8	4.4	1.4 U	32%
242-BLK-2R	2R	2.3 U	10.5	2.2 U	2.1 U	37%
242-BLK-3R	3R	1.5 U	15.1	2.7	3.7	53%
242-BLK-4R	4R	2.5 U	2.9 U	2.9	2.4 U	59%

TBT WATER BLANK AND MATRIX SPIKES

AMOUNT SPIKED : 222 NG/L

PERCENT RECOVERIES:

242-Spike/BLANK2 Amount Recovered:	59.9	154.1	165.6	NS	36%
Percent Recovery:	27%	62%	73%		
242-Spike/BLANK3 Amount Recovered:	24.7	136.1	167	NS	11%
Percent Recovery:	11%	55%	75%		
242-Spike/BLANK2 Amount Recovered:	47.2	142.3	130.9	NS	39%
Percent Recovery:	21%	59%	58%		
242-Spike/BLANK3 Amount Recovered:	60.3	209.9	177.1	NS	56%
Percent Recovery:	27%	88%	79%		
242-Spike/BLANK4 Amount Recovered:	39.7	169.0	148.2	NS	63%
Percent Recovery:	18%	76%	65%		
242-42 Matrix Spil Amount Recovered:	63.1	167.0	190.1	NS	22%
(OIANK-TBT-D2-1) Percent Recovery:	28%	66%	77%		

NS Indicates not spiked

WATER DATA

Project: OAKLAND
Sponsor: BRANNON/PRICE

(CF#242)

3/4/91

WATER PAH DATA

(Concentrations in ng/L)

SPONSOR CODE	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a) Anthracene	Chrysene
Lab. Method Blank	34.0 U	5.2 U	12.9 U	10.3 U	25.7	6.0 U	19.0	10.0	6.7	5.2 U
OOANK DAY 1 REP 1	81.0	11.1 U	30.0	22.2 U	185.8 B	23.0	35.1 B	81.3 B	13.0 U	11.1 U
OOANK DAY 1 REP 1 DUPLICATE	93.3	10.5 U	32.9	21.1 U	119.5 B	12.3 U	28.9 B	66.5 B	12.3 U	10.5 U
OOANK DAY 1 REP 2	115.7	12.5 U	31.3 U	25.1 U	33.4 U	14.6 U	22.0 B	80.5 B	14.6 U	12.5 U
OOANK DAY 1 REP 3	197.8	5.6 U	23.3	15.7	69.1 B	6.5 U	19.5 B	43.2 B	7.3 B	10.2
OOANK DAY 2 REP 1	49.1	4.4	21.3	8.7	31.1 B	7.1	29.9 B	71.8 B	11.3 B	12.6
OOANK DAY 2 REP 2	52.6	4.3 U	31.4	10.7	34.6 B	7.7	24.9 B	66.4 B	10.3	8.3
OOANK DAY 2 REP 3	48.4	4.6 U	26.1	9.2 U	26.6 B	7.1	22.7 B	59.0 B	7.1	8.7
OOANK DAY 7 REP 1	436.6	4.3 U	32.3	13.1	39.3 B	5.0 U	11.0 B	23.5 B	5.0 U	4.3
OOANK DAY 7 REP 2	184.2	4.8 U	29.5	10.3	29.1 B	5.5 U	7.9 U	16.4 B	5.5 U	4.8
OOANK DAY 7 REP 3	284.4	4.4 U	28.2	9.1	22.2 B	5.2 U	9.4 B	21.4 B	5.2 U	4.4
OOANK WATER BLANK	53.7	5.0 U	12.5 U	10.0 U	18.3 B	5.8 U	8.3 U	6.3 U	5.8 U	5.0 U
OOANK DAY 1 REP 1	62.7	4.2 U	10.5 U	8.4 U	16.1 B	4.9 U	13.7 B	55.2 B	4.9 U	7.2
OOANK DAY 1 REP 3	83.6	4.1 U	13.5	8.2 U	19.9 B	6.1	17.2 B	67.9 B	4.8 U	5.5
OOANK DAY 2 REP 1	33.3	4.6 U	11.6 U	9.2 U	22.1 B	5.4 U	19.7 B	58.8 B	5.4 U	5.9
OOANK DAY 2 REP 2	33.0	4.1 U	10.2 U	8.2 U	17.0 B	4.8 U	12.4 B	45.4 B	4.8 U	4.1
OOANK DAY 7 REP 1	27.0 U	4.1 U	10.3 U	8.2 U	20.9 B	4.8 U	17.9 B	42.6 B	4.8 U	4.1
OOANK DAY 7 REP 2	27.1 U	4.1 U	16.7	8.2 U	29.1 B	4.8 U	28.6 B	73.0 B	7.4	6.0
OOANK DAY 7 REP 3	28.6 U	4.3 U	17.0	8.7 U	33.6 B	5.4	34.2 B	82.9 B	7.9	7.0
OOANK WATER BLANK	32.7 U	5.0 U	12.4 U	9.9 U	19.9 B	5.8 U	12.5 B	9.7 B	5.8 U	5.0 U

U indicates analyte not detected at or above detection limit shown

• All benzofluoranthene isomers are quantified together

WATER DATA

Project: OAKLAND
Sponsor: BRANNON/PRICE

(CF#242)

3/4/91

(Concentrations in ng/L)

WATER PAH DATA

SURROGATE PERCENT RECOVERIES

SPONSOR CODE	Benzo(k)- uranthene	Benzo(a)- Pyrene	Indeno- (1,2,3-cd) Pyrene	Dibenz(a,h)- Anthracene	Benzo(ghi)- Perylene	D10 Fluor- ene	D10 Anth- racene	D10 Py- rene
Lab. Method Blank	6.5 U	5.2 U	8.2 U	4.7 U	4.1 U	84%	95%	86%
OOANK DAY 1 REP 1	13.9 U	11.1 U	17.6 U	10.2 U	8.9 U	95%	98%	84%
OOANK DAY 1 REP 1 DUPLICATE	13.2 U	10.5 U	16.7 U	9.7 U	8.4 U	92%	93%	82%
OIAK DAY 1 REP 2	15.7 U	12.5 U	19.9 U	11.5 U	10.0 U	74%	90%	85%
OOANK DAY 1 REP 3	7.3	16.5	8.9 U	5.1 U	4.5 U	80%	79%	76%
OOANK DAY 2 REP 1	22.2	27.6	6.7 U	3.9 U	9.6	89%	88%	79%
OOANK DAY 2 REP 2	5.3 U	6.5	6.8 U	3.9 U	4.4	91%	92%	85%
OOANK DAY 2 REP 3	17.0	8.0	7.3 U	4.2 U	5.8	79%	77%	70%
OOANK DAY 7 REP 1	5.4 U	4.3 U	6.8 U	4.0 U	3.5 U	91%	90%	83%
OOANK DAY 7 REP 2	5.9 U	4.8 U	7.5 U	4.4 U	3.8 U	94%	89%	81%
OOANK DAY 7 REP 3	5.5 U	4.4 U	7.0 U	4.1 U	3.5 U	94%	95%	91%
OOANK WATER BLANK	6.3 U	5.0 U	7.9 U	4.6 U	4.0 U	93%	93%	94%
OIAK DAY 1 REP 1	5.3 U	4.2 U	6.7 U	3.9 U	3.4 U	69%	67%	61%
OIAK DAY 1 REP 3	5.1 U	4.1 U	6.5 U	3.8 U	3.3 U	86%	69%	77%
OIAK DAY 2 REP 1	8.2	9.4	7.3 U	4.2 U	3.7 U	94%	83%	80%
OIAK DAY 2 REP 2	5.1 U	4.1 U	6.5 U	3.7 U	3.3 U	71%	63%	60%
OIAK DAY 7 REP 1	5.1 U	4.1 U	6.5 U	3.8 U	3.3 U	37%	38%	32%
OIAK DAY 7 REP 2	5.1 U	4.1 U	6.5 U	3.8 U	3.3 U	62%	61%	57%
OIAK DAY 7 REP 3	5.4 U	4.3 U	6.9 U	4.0 U	3.5 U	81%	71%	69%
OIAK WATER BLANK	6.2 U	5.0 U	7.9 U	4.5 U	4.0 U	93%	100%	86%

U indicates analyte not detected at or above detection limit shown

• All benzofluoranthene isomers are quantified together

242WATER

WATER DATA

Project: OAKLAND
Sponsor: BRANNON/PRICE

(CF#242)

3/4/91

WATER PAH QUALITY CONTROL DATA

Sample Spiked OIAK-D1-2

(Concentrations in ng/L)

METHOD BLANK

NAPHTHALENE
ACENAPHTHYLENE
ACENAPHTHENE
FLUORENE
PHENANTHRENE
ANTHRACENE
FLUORANTHENE
PYRENE
BENZ[<i>a</i>]ANTHRACENE
CHRYSENE
BENZO[<i>b</i> , <i>k</i>]FLUORANTHENE
BENZO[<i>a</i>]PYRENE
INDENO[1,2,3- <i>cd</i>]PYRENE
DIBENZ[<i>a,h</i>]ANTHRACENE
BENZO[<i>ghi</i>]PERYLENE
SURROGATE RECOVERY:
D10-FLUORENE
D10-ANTHRACENE
D10-PYRENE

34 U
5.2 U
13 U
10 U
25.7
6.1 U
19
8.99
6.68
5.2 U
6.5 U
5.2 U
8.18 U
4.74 U
4.13 U

MATRIX SPIKE		MATRIX SPIKE DUPLICATE	
Amount Spiked	Amount Recovered	Amount Spiked	Amount Recovered
1245	950	1310	1130
NS		NS	
NS		NS	
1245	1053	1310	1219
NS		NS	
1245	943	1310	1181
1245	1167	1310	1301
NS		NS	
1245	1388	1310	1582
NS		NS	
NS		NS	
1245	1104	1310	1563
NS		NS	
NS		NS	
1245	1003	1310	1318

Percent Recovered
67%
85%
76%
92%
111%
89%
81%

Percent Recovered
77%
93%
90%
98%
121%
119%
101%

NS indicates analyte not spiked
U indicates analyte not detected at or above detection limit shown
.. indicates outside of control limits (control limits: 50 - 150 %)

219WATER

WATER DATA

Project: OAKLAND
Sponsor: BRANNON/PRICE

(CF#219)

6/7/91

WATER METAL DATA

(Concentrations in UG/L)

Sample Number	Sponsor Code	Chromium Cr	Nickel Ni	Copper Cu	Zinc Zn	Arsenic As *	Selenium Se	Silver Ag **	Cadmium Cd	Mercury Hg	Lead Pb
219-1	OIKM6HR 1	4.50	8.39	6.94	15.46	4.32	1.74 U	0.50	0.33	0.07	0.70
219-2	OIKM6HR 2	4.94	8.08	7.05	16.11	4.05	1.74 U	0.54	0.48	0.15	0.30
219-3	OIKM6HR 3	6.03	8.60	8.03	12.09	4.86	1.74 U	0.56	0.34	0.21	0.32
219-4	OIKM D1 1	5.83	11.79	8.48	21.02	5.94	1.74 U	0.55	0.46	0.04	0.30
219-5	OIKM D1 2	4.55	10.78	8.92	14.65	4.86	1.74 U	0.55	0.37	0.04	0.33
219-6	OIKM D1 3	5.60	11.27	11.08	16.81	5.94	1.74 U	0.99	0.51	0.03	0.52
219-7	OIKM D2 1	5.10	11.69	9.63	50.83	8.37	1.74 U	0.82	0.53	0.05	0.98
219-8	OIKM D2 2	5.12	13.79	9.50	18.50	8.10	1.74 U	0.53	0.42	0.04	1.13
219-9	OIKM D2 3	5.41	13.43	9.69	20.43	9.18	1.74 U	0.58	0.45	0.04	0.67
219-10	OIKM D3 1	7.92	20.27	9.97	22.68	7.02	1.74 U	0.56	0.54	0.04	3.56
219-11	OIKM D3 2	5.56	11.81	9.08	18.23	7.58	1.74 U	0.74	0.52	0.04	0.48
219-11	OIKM D3 2	6.13	11.78	8.67	17.64	NA	1.74 U	0.55	0.49	NA	0.40
219-12	OIKM D3 3	6.78	15.95	8.85	16.25	7.02	1.74 U	0.56	0.47	0.08	1.54
219-13	OIKM D7 1	5.00	13.05	10.43	21.97	8.10	1.74 U	0.54	0.40	0.06	0.37
219-14	OIKM D7 2	5.10	13.28	9.87	21.46	4.32	1.74 U	0.53	0.49	0.04	0.30
219-15	OIKM D7 3	5.60	13.05	9.96	19.48	7.02	1.74 U	0.51	0.42	0.04	0.30
219-16 #1	OIKM D10 1	5.33	12.40	9.54	15.86	7.02	1.74 U	0.49	0.47	0.04	0.40
219-16 #2	OIKM D10 1	4.05	11.18	6.60	15.08	NA	1.74 U	0.53	0.38	NA	0.39
219-16 #3	OIKM D10 1	6.64	14.09	8.47	17.92	NA	1.74 U	0.52	0.52	NA	0.36
219-17	OIKM D10 2	5.62	16.19	9.26	37.82	8.37	1.74 U	0.61	0.60	0.03	0.53
219-18	OIKM D10 3	10.00	39.70	11.99	125.36	7.29	1.74 U	0.55	1.88	0.02	1.69
219-19	OIKM H20 BLK	0.81	2.03	1.81	43.01	0.94 U	1.74 U	0.72	0.50	0.01	0.36
219-20	OIANSM D1 1	4.90	10.57	8.65	12.04	5.40	1.74 U	0.69	0.38	0.02	0.35
218-21	OIANSM D1 2	1.16	16.89	9.75	24.42	6.48	1.74 U	0.93	0.28	0.01	0.72
218-22	OIANSM D1 3	1.83	20.53	15.51	16.01	4.86	1.74 U	1.01	0.44	0.03	1.16
218-23	OIANSM D2 1	7.25	73.94	50.21	67.89	22.95	1.74 U	0.85	0.94	0.01	2.69
218-24	OIANSM D2 2	8.18	21.94	41.41	61.69	15.93	1.74 U	0.71	1.15	0.01	4.03
218-25	OIANSM D2 3	6.34	24.48	42.88	146.33	27.54	1.74 U	0.52	0.46	0.01	5.58
218-26	OIANSM D3 1	30.62	39.68	56.24	73.39	18.09	1.74 U	0.38	0.02	0.02	19.00
218-27	OIANSM D3 2	23.36	34.95	55.99	82.75	16.47	1.74 U	0.77	0.26	0.01	16.23
218-28	OIANSM D3 3	30.84	41.15	66.28	88.93	21.60	1.74 U	0.40	0.21	0.01	22.61
218-29	OIANSM D4 1	9.33	12.54	23.68	33.91	19.71	1.74 U	0.42	1.00 U	0.00	6.83
218-30	OIANSM D4 2	11.75	15.11	29.42	41.59	17.28	1.74 U	0.42	1.00 U	0.02	8.64
218-31	OIANSM D4 3	10.25	13.10	18.78	33.84	14.58	1.74 U	0.39	1.00 U	0.01	7.71
218-32	OIANSM D5 1	5.95	8.35	16.72	42.16	12.42	1.74 U	0.34	1.00 U	0.01	4.90

219WATER

WATER DATA

Project: OAKLAND
Sponsor: BRANNONPRICE

(CF#219)

6/7/91

WATER METAL DATA

(Concentrations in UG/L)

Sample Number	Sponsor Code	Chromium Cr	Nickel Ni	Copper Cu	Zinc Zn	Arsenic As *	Selenium Se	Silver Ag **	Cadmium Cd	Mercury Hg	Lead Pb
218-33	OIANSM D5 2	7.65	8.03	17.47	34.32	10.26	1.74 U	0.65	1.00 U	0.01	5.46
218-34	OIANSM D5 3	5.83	7.19	14.84	36.01	12.42	1.74 U	0.42	1.00 U	0.01 U	4.79
218-35	OIANSM DG 1	10.92	14.62	21.23	71.48	7.29	1.74 U	0.44	1.00 U	0.01 U	9.40
218-36	OIANSM DG 2	1.00 U	1.00 U	1.00	1.00 U	5.94	1.74 U	0.67	1.00 U	0.01 U	0.23
219-37 #1	OIANSM DG 3	11.20	12.60	16.58	67.48	7.56	1.74 U	0.36	1.00 U	0.01	8.17
219-37 #2	OIANSM DG 3	12.23	14.40	20.43	78.89	NA	1.74 U	0.35	1.00 U	NA	9.74
219-37 #3	OIANSM DG 3	14.95	15.50	20.08	79.74	NA	1.74 U	0.33	1.00 U	NA	9.63
219-38	OIANSM D7 1	8.06	8.10	13.23	40.96	3.78	1.74 U	0.78	1.00 U	0.01	6.62
219-39	OIANSM D7 2	8.85	10.25	14.47	37.73	7.02	1.74 U	0.49	1.00 U	0.01	6.72
219-40	OIANSM D7 3	10.16	48.75	36.86	325.30	6.21	1.74 U	0.38	0.30	0.01	16.62
219-41	OIANSM H2O BLK	1.81	7.11	1.60	10.11	0.94 U	1.74 U	0.95	1.00 U	0.01	1.04
219-43	OOKM 6HR 2	6.68	39.27	30.80	33.92	11.61	1.74 U	1.38	1.00 U	0.05	0.74
219-44	OOKM 6HR 3	3.92	50.39	37.40	45.04	17.28	1.74 U	1.33	1.00 U	0.09	0.95
219-45	OOKM D1 1	3.97	49.08	36.59	55.15	31.05	1.74 U	1.51	0.15	0.06	0.93
219-46	OOKM D1 2	4.29	51.91	38.28	47.04	28.35	1.74 U	1.50	0.55	0.05	0.90
219-47	OOKM D1 3	4.62	83.56	47.70	74.24	33.48	1.74 U	1.53	0.24	0.05	1.04
219-48	OOKM D2 1	10.12	63.78	43.87	52.66	42.39	1.74 U	1.46	0.58	0.00	0.64
219-49	OOKM D2 2	11.74	53.49	47.07	33.00	56.77	1.74 U	2.49	0.61	0.01	0.63
219-50	OOKM D2 3	20.69	64.11	46.87	43.31	52.72	1.74 U	1.62	1.00 U	0.01	0.87
219-51	OOKM D3 1	7.51	55.76	47.48	24.10	101.38	1.74 U	1.76	0.79	0.06	0.71
219-52 #1	OOKM D3 2	8.62	61.75	54.94	31.71	125.71	1.74 U	1.53	0.34	0.06	0.90
219-52 #2	OOKM D3 2	12.23	51.84	59.94	24.33	NA	1.74 U	1.85	0.60	NA	0.75
219-53	OOKM D3 3	11.68	53.77	61.76	25.28	101.38	1.74 U	1.56	0.40	0.06	0.79
219-54	OOKM D7 1	10.85	47.67	60.44	24.76	77.05	1.74 U	1.80	0.88	0.06	4.68
219-55 #1	OOKM D7 2	7.20	52.62	46.67	27.69	60.83	1.74 U	2.31	0.32	0.07	1.05
219-55 #2	OOKM D7 2	8.44	61.23	56.38	31.21	NA	1.74 U	1.79	0.62	NA	0.96
219-55 #3	OOKM D7 2	8.37	57.60	56.55	28.77	NA	1.74 U	1.64	0.38	NA	1.03
219-56	OOKM D7 3	9.05	58.70	55.56	24.94	77.05	1.74 U	1.67	0.62	0.06	0.71
219-57	OOKM D10 1	12.83	58.76	53.49	25.74	174.37	1.74 U	1.78	0.38	0.12	0.66
219-58	OOKM D11 2	9.78	55.94	51.14	35.04	113.54	1.74 U	1.89	0.35	0.07	0.92
219-59 #1	OOKM D11 3	9.70	62.46	56.25	35.14	145.98	1.74 U	1.68	0.67	0.07	0.89
219-59 #2	OOKM D11 3	3.99	12.81	7.25	21.67	NA	1.74 U	1.53	1.73	NA	1.79
219-60	OOKM H2O BLANK	0.35	9.92	3.97	26.17	0.94 U	1.74 U	1.13	1.00 U	0.02	0.48
219-61	OOANSM D1 1	2.87	14.77	4.15	10.77	31.05	1.74 U	0.49	0.16	0.05	0.78
219-62	OOANSM D1 2	3.14	17.71	8.29	12.71	28.35	1.74 U	0.37	0.15	0.03	0.58

219WATER

WATER DATA

Project: OAKLAND
Sponsor: BRANNON/PRICE

(CF#219)

6/7/91

WATER METAL DATA

(Concentrations in UG/L)

Sample Number	Sponsor Code	Chromium Cr	Nickel Ni	Copper Cu	Zinc Zn	Arsenic As *	Selenium Se	Silver Ag **	Cadmium Cd	Mercury Hg	Lead Pb
219-63	OOANSM D13	3.10	32.86	16.89	25.93	29.16	1.74 U	0.39	0.14	0.06	2.80
219-64	OOANSM D21	11.86	37.07	59.14	41.18	23.76	1.74 U	0.63	0.48	0.01 U	31.62
219-65	OOANSM D22	9.40	17.26	51.79	47.16	17.28	1.74 U	0.27	0.45	0.01 U	24.53
219-66	OOANSM D23	8.01	14.82	40.78	51.54	21.60	1.74 U	0.54	0.61	0.01 U	18.51
219-67	OOANSM D31	92.49	104.71	404.92	221.76	28.62	1.74 U	0.32	1.51	NA	151.69
219-68	OOANSM D32	47.03	60.79	164.13	131.67	29.16	1.74 U	0.27	0.79	0.05	58.03
219-69	OOANSM D33	42.62	61.61	177.05	132.90	36.72	1.74 U	0.25	0.81	0.09	59.05
219-70	OOANSM D41	17.04	23.17	69.56	49.91	39.98	1.74 U	0.24	0.23	0.03	18.21
219-71	OOANSM D42	18.48	23.10	60.86	46.21	38.34	1.74 U	0.25	0.23	0.02	19.05
219-72	OOANSM D43	26.12	30.71	100.55	63.27	42.12	1.74 U	0.40	0.48	0.03	28.76
219-73	OOANSM D51	12.99	18.01	30.94	80.85	30.51	1.74 U	0.26	0.30	0.03	15.05
219-74	OOANSM D52	13.45	16.48	32.61	48.02	25.65	1.74 U	0.25	0.22	0.04	13.50
219-75	OOANSM D53	13.30	16.44	31.03	60.71	29.16	1.74 U	0.24	0.37	0.02	13.62
219-76	OOANSM D61	26.06	26.18	58.49	72.49	13.77	1.74 U	0.23	0.38	0.05	32.80
219-77 #1	OOANSM D62	6.07	6.40	16.78	25.55	1.62	1.74 U	0.27	0.18	0.01	6.47
219-77 #2	OOANSM D62	5.64	6.79	13.10	25.39	NA	1.74 U	0.29	0.20	NA	5.43
219-77 #3	OOANSM D62	5.85	6.44	12.97	25.77	NA	1.74 U	0.30	0.22	NA	5.40
219-78	OOANSM D63	20.26	22.73	37.08	84.51	11.34	1.74 U	0.34	0.52	0.02	22.05
219-79	OOANSM D71	0.97	3.74	9.37	17.54	0.94 U	1.74 U	0.22	0.27	0.01 U	1.27
219-80	OOANSM D72	8.68	10.18	12.44	24.27	0.94 U	1.74 U	0.39	0.20	0.01	7.93
219-81	OOANSM D7-3	NA	NA	NA	NA	0.94 U	1.74 U	NA	NA	0.01 U	NA
219-82	OOANSM H20 BLANK	NA	NA	NA	NA	0.94 U	1.74 U	NA	NA	0.01	NA

U Indicates not detected at detection limit shown

NA Indicates not analyzed

* As values may be slightly high due to saltwater interferences

** Ag values may be low due to precipitation of AgCl

219WATER

STANDARD REFERENCE MATERIAL:

1643b	1643b REP 1A	17.70	46.74	20.40	67.58	NA	NA	13.06	21.39	24.78
1643b	1643b REP 1B	19.00	48.61	20.54	67.10	NA	NA	11.83	20.37	21.84
1643b	1643b REP 2A	18.97	48.49	20.08	68.91	NA	NA	12.71	20.40	25.04
1643b	1643b REP 2B	19.07	46.53	19.54	66.19	NA	NA	11.77	20.41	26.49
1643b	1643b REP 3A	20.28	55.67	23.57	73.51	NA	NA	12.57	20.67	21.15
1643b	1643b REP 3B	21.08	60.34	31.65	76.36	NA	NA	13.52	21.09	18.59
1643b	1643b EP 4A	17.60	43.56	19.14	62.16	NA	NA	12.30	21.13	25.44
1643b	1643b REP 4B	19.82	49.85	22.08	70.38	NA	NA	12.29	21.78	23.53

CERTIFIED VALUES 18.6 49 21.9 66 ~ 49 9.7 20 NC 23.7

SLRS rep 1
SLRS rep 2
SLRS rep 3
SLRS rep 4
CERTIFIED VALUE:

0.94 U
0.94 U
0.94 U
0.94 U
0.77
±0.09

NA Indicates not analyzed
: Indicates not certified
MATRIX SPIKE RESULTS

(Concentrations in ug/L)

219WATER

MATRIX SPIKE RESULTS
(Concentrations in ug/L)

Sample Number	Sponsor Code	Chromium Cr	Nickel Ni	Copper Cu	Zinc Zn	Arsenic As *	Selenium Se	Silver Ag **	Cadmium Cd	Mercury Hg	Lead Pb
SAMPLE SPIKED:	OIKM D10 1	5.34	12.56	8.21	16.29			0.51	0.46		0.38
AMOUNT SPIKED:		10	10	10	10			10	10		10
AMOUNT RECOVERED:		20.6	26.1	22	30.6	NS	NS	11.8	11.2	NS	7.15
PERCENT RECOVERY:		153%	135%	138%	143%			113%	107%		68%
SAMPLE SPIKED:	OIKM D10 1	5.34	12.58	8.21	16.29			0.51	0.46		0.38
AMOUNT SPIKED:		50	50	50	50			50	50		50
AMOUNT RECOVERED:		67.4	73.1	70.4	73.4	NS	NS	43.3	50.7	NS	37.7
PERCENT RECOVERY:		124%	121%	124%	114%			86%	100%		75%
SAMPLE SPIKED:	OIANSM DG 3	12.79	14.17	19.02	75.37	7.56	NS	0.35	1.00		9.18
AMOUNT SPIKED:		10	10	10	10	8.91		10	10		10
AMOUNT RECOVERED:		23.2	25	27.9	82.6	15.39		6.58	10.4	NS	18.9
PERCENT RECOVERY:		104%	108%	89%	72%	88%		62%	94%		97%
SAMPLE SPIKED:	OIANSM DG 3	12.79	14.17	19.02	75.37	NS	NS	0.35	1.00		9.18
AMOUNT SPIKED:		50	50	50	50			50	50		50
AMOUNT RECOVERED:		60.6	64.7	67.8	122			39.1	51.5	NS	59.1
PERCENT RECOVERY:		96%	101%	96%	93%			78%	101%		100%
SAMPLE SPIKED:	OOKM D7 2	8.00	57.15	53.20	29.23			1.91	0.44		1.01
AMOUNT SPIKED:		10	10	10	10			10	10		10
AMOUNT RECOVERED:		23.6	60	67.6	39	NS	NS	3.35	10.1	NS	5.75
PERCENT RECOVERY:		156%	28%	144%	98%			14%	97%		47%
SAMPLE SPIKED:	OOKM D7 2	8.00	57.15	53.20	29.23			1.91	0.44		1.01
AMOUNT SPIKED:		50	50	50	50			50	50		50
AMOUNT RECOVERED:		83	113	127	87.9	NS	NS	11.2	50.4	NS	24.3
PERCENT RECOVERY:		150%	112%	148%	117%			19%	100%		47%

219WATER

(Concentrations in ug/L)

MATRIX SPIKE RESULTS

Sample Number	Sponsor Code	Chromium Cr	Nickel Ni	Copper Cu	Zinc Zn	Arsenic As *	Selenium Se	Silver Ag **	Cadmium Cd	Mercury Hg	Lead Pb
SAMPLE SPIKED:	OOANSM D6 2	5.85	6.54	14.28	25.57			0.29	0.20		5.77
AMOUNT SPIKED:		10	10	10	10			10	10		10
AMOUNT RECOVERED:		15.7	15.6	21.7	35.2	NS	NS	5.09	10.6	NS	14.1
PERCENT RECOVERY:		98%	91%	74%	96%			48%	104%		83%
SAMPLE SPIKED:	OOANSM D6 2	5.85	6.54	14.28	25.57			0.29	0.20		5.77
AMOUNT SPIKED:		50	50	50	50			50	50		50
AMOUNT RECOVERED:		53	50.9	54.2	69.5	NS	NS	26.5	50	NS	49.4
PERCENT RECOVERY:		94%	89%	80%	88%			52%	100%		87%

NS indicates not spiked

PAH RESULTS FOR OAKLAND INNER AND OUTER WATERS
(Concentrations in ng/L, ppb)

Project: OAKLAND
Sponsor: C. Price/Brannon
Batelle #: 278

(Concentrations in ng/L, ppb)										
Client Code	Sponsor Code	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)-Anthracene
Lab Method Blank										
278-1	OIANS-PAH D1-1	37.4	9.8 U	9.8 U	9.8 U	18.8	9.8 U	14.6	50.6	9.8 U
278-2	OIANS-PAH D1-2	29.6	8.9 U	8.9 U	8.9 U	12.1	8.9 U	11.7	40.3	8.9 U
278-3	OIANS-PAH D1-3	41.7	22.2 U	22.2 U	22.2 U	23.8	22.2 U	22.2 U	77.0	22.2 U
278-4	OIANS-PAH D2-1	37.9	9.9 U	9.9 U	9.9 U	26.4	9.9 U	34.0	125.2	12.3
278-5	OIANS-PAH D2-2	36.9	11.6 U	11.6 U	11.6 U	27.8	11.6 U	28.5	116.7	11.6 U
278-6	OIANS-PAH D2-3	32.6	10.6 U	10.6 U	10.6 U	22.6	10.6 U	30.5	129.6	10.8
278-7	OIANS-PAH D3-1	54.4	11.6 U	11.6 U	11.6 U	60.2	11.6 U	57.5	187.7	13.5
278-8	OIANS-PAH D3-2	37.4	9.9 U	10.9	9.9 U	47.3	11.7	73.0	292.8	20.2
278-9	OIANS-PAH D3-3	40.1	10.4 U	16.4	15.9	66.2	20.6	131.2	516.8	37.4
278-10	OIANS-PAH D4-1	41.7	15.2 U	15.2 U	15.2 U	35.6	15.2 U	70.7	249.3	24.6
278-11	OIANS-PAH D4-2	29.6	12.4 U	12.4 U	12.4 U	35.9	12.4 U	75.3	258.6	19.8
278-12	OIANS-PAH D4-3	18.4	11.8 U	11.8 U	11.8 U	33.4	11.8 U	59.0	205.7	19.0
278-13	OIANS-PAH D5-1	22.0	14.7 U	14.7 U	14.7 U	32.5	14.7 U	65.1	204.2	24.5
278-14	OIANS-PAH D5-2	33.2	13.8 U	19.2	16.1	119.9	13.8 U	102.6	182.0	29.5
278-15	OIANS-PAH D5-3	19.9	12.3 U	12.3 U	12.3 U	38.8	12.3 U	50.0	143.7	23.9
Lab Method Blank										
278-16	OIANS-PAH D6-1	11.4 U	11.4 U	11.4 U	11.4 U	11.4 U	11.4 U	11.4 U	11.4 U	11.4 U
278-17	OIANS-PAH D6-2	19.2	11.8 U	11.8 U	11.8 U	42.3	11.8 U	71.0	214.9	22.8
278-18	OIANS-PAH D6-3	16.5	13.9 U	13.9 U	13.9 U	46.2	13.9 U	94.7	288.2	28.6
278-19	OIANS-PAH H20 BLK	17.5	16.0 U	16.0 U	16.0 U	47.0	16.0 U	72.2	204.6	30.4
278-20	OIANS-PAH D1-1	51.5	11.0 U	11.0 U	11.0 U	42.3	11.0 U	11.0 U	11.0 U	11.0 U
278-21	OIANS-PAH D1-2	25.3	9.3 U	14.4	9.3 U	43.2	9.3 U	20.1	39.2	9.3 U
278-22	OIANS-PAH D1-3	28.4	9.1 U	15.4	9.1 U	41.0	9.1 U	19.4	39.4	9.1 U
278-23	OIANS-PAH D2-1	22.3	9.0 U	13.2	9.0 U	35.7	9.0 U	16.5	30.8	9.0 U
278-24	OIANS-PAH D2-2	17.8	9.4 U	9.5	9.4 U	14.1	9.4 U	19.4	43.5	9.4 U
		37.6	21.7 U	21.7 U	21.7 U	48.6	21.7 U	51.5	107.6	21.7 U

PAH RESULTS FOR OAKLAND INNER AND OUT
(Concentrations in ng/L, ppb)

Project: OAKLAND
Sponsor: C. Price/Brannon
Batelle #: 278

Client Code	Sponsor Code	Benzo(b)- Benzo(k)- Flouranthene			Benzo(a)- Pyrene	Indeno- (1,2,3-cd) Pyrene	Dibenz(a,h)- Anthracene	Benzo(ghi)- Perylene	Surrogate Percent Recovery		
		Chrysene	Benzo(k)- Flouranthene	Benzo(b)- Benzo(k)- Flouranthene					D10 Fluor- ene	D10 Anth- racene	D10 Py- rene
Lab Method Blank		11.3 U	16.9 U	11.3 U	11.3 U	11.3 U	11.3 U	11.3 U	57.5	83.1	73.2
278-1	OIANS-PAH D1-1	9.8 U	14.7 U	9.8 U	9.8 U	9.8 U	9.8 U	9.8 U	62.8	65.6	58.6
278-2	OIANS-PAH D1-2	8.9 U	13.4 U	8.9 U	8.9 U	8.9 U	8.9 U	8.9 U	60.8	78.2	60.8
278-3	OIANS-PAH D1-3	22.2 U	33.3 U	22.2 U	22.2 U	22.2 U	22.2 U	22.2 U	62.2	50.8	58.3
278-4	OIANS-PAH D2-1	28.3	66.3	38.2	38.2	15.1	9.9 U	17.1	75.0	87.9	59.3
278-5	OIANS-PAH D2-2	12.1	64.7	15.0	13.9	13.9	11.6 U	24.7	65.8	40.9	64.3
278-6	OIANS-PAH D2-3	13.8	56.7	32.8	10.8	10.8	10.6 U	21.4	71.3	66.5	60.7
278-7	OIANS-PAH D3-1	11.6 U	77.4	65.3	20.7	20.7	11.6 U	33.9	63.4	83.6	68.9
278-8	OIANS-PAH D3-2	11.9	99.9	74.6	17.4	17.4	9.9 U	23.3	70.8	93.2	69.9
278-9	OIANS-PAH D3-3	32.5	197.4	138.1	42.2	42.2	10.4 U	46.5	87.8	96.3	66.6
278-10	OIANS-PAH D4-1	15.2 U	96.9	73.1	22.5	22.5	15.2 U	28.7	73.5	87.3	72.0
278-11	OIANS-PAH D4-2	17.7	101.0	75.3	18.5	18.5	12.4 U	22.7	80.1	81.9	65.4
278-12	OIANS-PAH D4-3	14.3	78.9	57.4	12.3	12.3	11.8 U	16.3	70.5	83.3	67.8
278-13	OIANS-PAH D5-1	17.8	106.8	87.1	19.6	19.6	14.7 U	26.1	57.1	77.5	73.9
278-14	OIANS-PAH D5-2	35.9	111.7	65.2	31.7	31.7	13.8 U	31.0	58.1	62.5	73.4
278-15	OIANS-PAH D5-3	18.4	93.8	66.5	20.1	20.1	12.3 U	28.1	53.9	66.2	68.0
Lab Method Blank		11.4 U	17.0 U	11.4 U	11.4 U	11.4 U	11.4 U	11.4 U	54.2	78.6	69.7
278-16	OIANS-PAH D6-1	27.5	109.9	54.7	13.0	13.0	11.8 U	19.7	60.5	74.5	68.9
278-17	OIANS-PAH D6-2	34.1	243.6	100.9	25.5	25.5	13.9 U	37.6	51.2	61.7	64.6
278-18	OIANS-PAH D6-3	38.7	123.0	66.5	16.0 U	16.0 U	16.0 U	26.2	45.3	62.7	68.9
278-19	OIANS-PAH H20 BLK	11.0 U	16.5 U	11.0 U	11.0 U	11.0 U	11.0 U	11.0 U	62.1	62.5	81.7
278-20	OOANS-PAH D1-1	9.3 U	13.9 U	9.3 U	9.3 U	9.3 U	9.3 U	9.3 U	46.8	83.0	69.6
278-21	OOANS-PAH D1-2	9.1 U	13.6 U	9.1 U	9.1 U	9.1 U	9.1 U	9.1 U	48.3	43.9	68.7
278-22	OOANS-PAH D1-3	9.0 U	13.4 U	9.0 U	9.0 U	9.0 U	9.0 U	9.0 U	43.2	66.6	46.1
278-23	OOANS-PAH D2-1	9.4 U	14.1 U	9.4 U	9.4 U	9.4 U	9.4 U	9.4 U	47.0	75.3	52.5
278-24	OOANS-PAH D2-2	21.7 U	49.3	27.4	21.7 U	21.7 U	21.7 U	21.7 U	51.7	85.5	54.1

PAH RESULTS FOR OAKLAND INNER AND OUTER WATERS
(Concentrations in ng/L, ppb)

Project: OAKLAND
Sponsor: C. Price/Brannon
Batelle #: 278

(Concentrations in ng/L, ppb)										
Client Code	Sponsor Code	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)-Anthracene
Lab Method Blank										
278-25	OOANS-PAH D2-3	11.4 U	11.4 U	11.4 U	11.4 U	11.4 U	11.4 U	11.4 U	11.4 U	11.4 U
278-26	OOANS-PAH D3-1	18.9	9.2 U	10.3	9.2 U	11.7	9.2 U	13.3	28.7	9.2 U
278-27	OOANS-PAH D3-2	18.2	11.8 U	11.8 U	11.8 U	34.3	11.8 U	113.3	38.4	11.8 U
278-28	OOANS-PAH D3-3	17.2	11.3 U	11.3 U	11.3 U	17.9	11.3 U	51.9	16.8	11.3 U
278-29	OOANS-PAH D4-1	14.7	12.7 U	12.7 U	12.7 U	14.0	12.7 U	25.9	12.7 U	12.7 U
278-29	OOANS-PAH D4-1	38.5	14.3 U	14.3 U	14.3 U	24.0	14.3 U	49.0	146.3	19.1
278-30	OOANS-PAH D4-2	52.9	17.4 U	17.4 U	17.4 U	38.0	17.4 U	98.3	287.5	32.3
278-31	OOANS-PAH D4-3	40.1	11.4 U	15.3	14.3	58.0	18.5	133.7	361.4	38.3
278-32	OOANS-PAH D5-1	20.2	13.2 U	13.2 U	13.2 U	26.4	13.2 U	43.5	117.0	13.2 U
278-33	OOANS-PAH D5-2	16.0	13.5 U	13.5 U	13.5 U	28.1	13.5 U	70.1	182.6	22.3
278-34	OOANS-PAH D5-3	14.1	12.6 U	12.6 U	12.6 U	12.6	12.6 U	47.0	130.9	16.0
278-35	OOANS-PAH D6-1	18.7	12.6 U	12.6 U	12.6 U	23.1	12.6 U	73.0	191.7	23.3
278-36	OOANS-PAH D6-2	40.9 U	40.9 U	40.9 U	40.9 U	40.9 U	40.9 U	125.2	337.1	43.1
278-37	OOANS-PAH D6-3	32.8	14.2 U	14.2 U	14.2 U	40.1	14.2 U	128.6	344.6	32.6
278-38	OOANS-PAH H2O BLK	24.9	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U

U indicates not detected at detection limit shown.

PAH RESULTS FOR OAKLAND INNER AND OUT
(Concentrations in ng/L, ppb)

Project: OAKLAND
Sponsor: C. Price/Brannon
Batelle #: 278

Client Code	Sponsor Code	Benzo(b)- Benzo(k)- Flouranthene				Indeno- (1,2,3-cd) Pyrene	Dibenz(a,h)- Anthracene	Benzo(ghi)- Perylene	Surrogate Percent Recovery				
		Chrysene	Benzo(a)- Pyrene	Benzo(a)- Pyrene	D10 Fluor- ene				D10 Anth- racene	D10 Py- rene			
Lab Method Blank													
		11.4 U	17.1 U	11.4 U	11.4 U	11.4 U	11.4 U	11.4 U	51.4	71.3	57.2		
278-25	OOANS-PAH D2-3	9.2 U	13.7 U	9.2 U	9.2 U	9.2 U	9.2 U	9.2 U	58.1	52.1	52.2		
278-26	OOANS-PAH D3-1	29.1	154.6	11.8 U	11.8 U	15.4	11.8 U	11.8 U	58.8	53.8	43.7		
278-27	OOANS-PAH D3-2	18.8	81.8	11.3 U	11.3 U	11.3 U	11.3 U	11.3 U	52.6	65.7	46.4		
278-28	OOANS-PAH D3-3	12.7 U	34.9	12.7 U	12.7 U	12.7 U	12.7 U	12.7 U	54.8	67.5	51.0		
278-29	OOANS-PAH D4-1	16.1	83.2	44.9	44.9	17.2	14.3 U	28.6	62.5	74.4	50.6		
278-30	OOANS-PAH D4-2	29.8	157.0	91.3	91.3	40.2	17.4 U	65.7	58.9	62.2	44.5		
278-31	OOANS-PAH D4-3	36.0	182.8	64.1	64.1	35.5	11.4 U	62.5	57.5	49.1	51.4		
278-32	OOANS-PAH D5-1	13.2 U	48.1	24.1	24.1	13.2 U	13.2 U	13.2 U	65.2	72.3	54.5		
278-33	OOANS-PAH D5-2	21.0	73.8	41.3	41.3	13.5 U	13.5 U	21.5	64.4	73.2	64.7		
278-34	OOANS-PAH D5-3	13.3	59.0	31.7	31.7	12.6 U	12.6 U	22.7	76.1	78.8	66.2		
278-35	OOANS-PAH D6-1	19.5	73.6	32.9	32.9	12.6 U	12.6 U	16.6	69.8	62.2	54.2		
278-36	OOANS-PAH D6-2	47.7	220.1	74.3	74.3	40.9 U	40.9 U	77.2	59.0	48.9	55.7		
278-37	OOANS-PAH D6-3	30.6	176.6	40.6	40.6	24.7	14.2 U	44.6	62.5	33.6	45.7		
278-38	OOANS-PAH H20 BLK	10.0 U	15.0 U	10.0 U	10.0 U	10.0 U	10.0 U	10.0 U	67.4	71.0	69.1		

U indicates not detected at detection limit shown.

PAH RESULTS FOR OAKLAND INNER AND OUTER WATERS
(Concentrations in ng/L, ppt)

Project: OAKLAND
Sponsor: C. Price/Brannon
Batelle #: 278

MATRIX SPIKE RESULTS

		Naphthalene	Fluorene	Anthracene	Fluoranthene	Benzo[a]- anthracene	Benzo[a]- pyrene	Benzo[ghi]- perylene
278-3 MS	MATRIX SPIKE I	813.0	981.0	1024.0	1360.0	1283.0	1467.0	1282.0
OIANS-PAH D1-3	Amount Spiked	1567.0	1567.0	1567.0	1567.0	1567.0	1567.0	1567.0
	Sample Amount	41.7	0.0	0.0	0.0	0.0	0.0	0.0
	% Recovery	49%	63%	65%	87%	82%	94%	82%
278-3 MSD	MATRIX SPIKE I DUP	751.0	1059.0	1153.0	1467.0	1571.0	1715.0	1501.0
OIANS-PAH D1-3	Amount Spiked	1667.0	1667.0	1667.0	1667.0	1667.0	1667.0	1667.0
	Sample Amount	41.7	0.0	0.0	0.0	0.0	0.0	0.0
	% Recovery	43%	64%	69%	88%	94%	103%	90%
278-24 MS	MATRIX SPIKE II	512.0	957.0	1267.0	1487.0	1545.0	1477.0	1165.0
OOANS-PAT D2-2	Amount Spiked	1604.0	1604.0	1604.0	1604.0	1604.0	1604.0	1604.0
	Sample Amount	37.6	0.0	0.0	51.5	0.0	27.4	0.0
	% Recovery	30%	60%	79%	90%	96%	90%	73%
278-24 MSD	MATRIX SPIKE II DUP	483.0						
OOANS-PAT D2-2	Amount Spiked	1689.0	1689.0	1689.0	1689.0	1689.0	1689.0	1689.0
	Sample Amount	37.6	0.0	0.0	51.5	0.0	27.4	0.0
	% Recovery	26%	55%	80%	92%	95%	90%	68%
278-36 MS	MATRIX SPIKE III	765.0	1062.0	920.0	1500.0	1308.0	1166.0	1402.0
OOANS-PAT D6-2	Amount Spiked	1734.0	1734.0	1734.0	1734.0	1734.0	1734.0	1734.0
	Sample Amount	0.0	0.0	0.0	125.0	43.0	74.0	77.0
	% Recovery	34%	61%	53%	79%	73%	63%	76%
278-36 MSD	MATRIX SPIKE III DUP	830.0	1080.0	1000.0	1375.0	1202.0	1114.0	1224.0
OOANS-PAT D6-2	Amount Spiked	1821.0	1821.0	1821.0	1821.0	1821.0	1821.0	1821.0
	Sample Amount	0.0	0.0	0.0	125.0	43.0	74.0	77.0
	% Recovery	45%	59%	55%	68%	63%	57%	0.63

* Values outside of QC limits (50-150%).

337 METALS DATA

8/21/91

OAKLAND INNER (BRANNON) (CF#337)

WATER METAL RESULTS

(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb
		ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	AA	ICP-MS	ICP-MS	CVAA	ICP-MS
337-77	OIAS-M-BLANK	0.2	0.5	1.4	5.7	0.4		1.15	0.02	0.00129	0.14
337-78	OIAS-M-D1#1	3	4.8	16.4	8.2	3.5		0.02	0.08	0.01544	2.95
337-79	OIAS-M-D1#2	2.9	5	15.5	9.5	3.6		1.08	0.08	0.0317	3.06
337-80	OIAS-M-D1#3	2.8	4.3	14.1	6.8	4.7		1.14	0.08	0.01613	2.72
337-81	OIAS-M-D2#1	30.8	42.3	50.4	103	7.3		1.09	0.63	0.00242	25.9
337-82	OIAS-M-D2#2	166	153	255	376	37.1		1.52	4.02	0.03652	146
337-83	OIAS-M-D2#3	92.1	103	123	202	16		1.21	0.85	0.00712	76.4
337-84	OIAS-M-D3#1	23.2	26.1	30.5	49	19.4		1.2	0.3	0.18908	16.7
337-85	OIAS-M-D3#2	32.7	31.4	40.3	52.4	36.1		1.23	0.13	0.02637	20.1
337-86	OIAS-M-D3#3	26.4	25.3	35.4	43.9	33.3		1.16	0.2	0.01164	16.1
337-87	OIAS-M-D4#1	25.3	29	33.6	50.8	14.7		1.16	0.26	0.00739	20.7
337-88	OIAS-M-D4#2	23.6	24.9	38.4	80.8	24.8		1.13	0.52	0.01254	21.3
337-89	OIAS-M-D4#3	25.3	25.9	36.9	51.9	23.1		1.19	0.2	0.01257	19.8
337-90	OIAS-M-D5#1	30	32	35.1	65.8	10.7		1.17	0.5	0.05184	22.4
337-91	OIAS-M-D5#2	30	29.6	38.6	62.1	13.4		1.13	0.47	0.03077	24
337-92	OIAS-M-D5#3	10.4	12.2	13.9	33.2	8.4		1.2	0.11	0.00168	6.95
337-93	OIAS-M-D6#1	11.4	13.9	16.3	41.1	13.9		1.16	0.29	0.00354	8.11
337-94	OIAS-M-D6#2	10.5	11.4	16.5	22.5	12.3		1.17	0.15	0.00199	7.72
337-95	OIAS-M-D6#3	12.9	16.9	62.6	49.1	14.7		1.47	0.3	0.02318	14.5
337-96	OOAS-M-D1#1	8.7	13.4	68.5	19.5	15.3		1.48	0.32	0.05488	9.75
337-97	OOAS-M-D1#2	10.3	14.1	59.3	22	14.5		1.43	0.31	0.02865	10.5
337-98	OOAS-M-D1#3	144	134	220	368	34.9		1.43	2.59	0.06907	144

337 METALS DATA

8/21/91

OAKLAND INNER (BRANNON) (CF#337)

WATER METAL RESULTS

(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As ICP-MS	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVAA	Pb ICP-MS
337-99	OOAS-M-D2#1	98.7	108	136	214	16.1		1.35	1.24	0.00767	85.1
337-100	OOAS-M-D2#2	114	117	216	304	23.4		1.47	2.81	0.03215	125
337-101	OOAS-M-D2#3	36.4	32.8	60.5	72.1	51.8		1.32	0.46	0.03708	33.8
337-102	OOAS-M-D3#1	34.7	33.3	64.2	73.2	45.6		1.29	0.42	0.01377	36.7
337-103	OOAS-M-D3#2	34.3	32.1	59.1	64.3	43.7		1.3	0.4	0.02441	32.6
337-104	OOAS-M-D3#3	62.5	57.3	96.5	134	47.9		1.36	0.8	0.01719	63.3
337-105	OOAS-M-D4#1	51.1	67.6	89	146	27		1.34	0.82	0.00879	63.6
337-106	OOAS-M-D4#2	63.6	60	91.7	137	30.6		1.25	0.87	0.01796	67.2
337-107	OOAS-M-D4#3	42.7	48.5	60.6	103	38.1		1.3	1.03	0.0134	38
337-108	OOAS-M-D5#1	34.4	33.3	53.4	83.4	27		1.29	0.64	0.01552	34.8
337-109	OOAS-M-D5#2	39.9	37.7	55.8	100	29.2		1.41	0.56	0.01137	41.4
337-110	OOAS-M-D5#3	10.9	11.3	21.8	27.7	24.9		1.17	0.16	0.00485	11.5
337-111	OOAS-M-D6#1	9	10.3	17.8	26.9	18.3		1.2	0.33	0.00586	9.69
337-112	OOAS-M-D6#2	10.2	11.6	20.6	28.9	26.4		1.19	0.13	0.00421	11.7
337-113	OOAS-M-D6#3	30	29.2	48.3	70.1	21.4		1.23	0.68	0.00625	32
337-114	OOAS-M-D7#1	23.9	21.9	39.6	69.4	14		1.28	0.63	0.00416	28.2
337-115	OOAS-M-D7#2	46.3	44	56	120	28.4		1.39	0.8	0.0082	28.8
3370-116	OOAS-M-D7#3	1.8	0.8	2.5	3.4	13.6		2.53	0.04	0.00494	0.27
337-117	OIAS-M-D7#1	26.7	31.2	31	54.5	12.9		1.16	0.69	0.00351	13.1
337-118	OIAS-M-D7#2	27.4	33	29.4	76.1	16.4		1.15	0.25	0.00762	14
337-119	OIAS-M-D7#3	27.1	28.7	35.6	47	14.2		1.18	0.34	0.00438	16.1

337 METALS DATA

8/21/91

OAKLAND INNER (BRANNON) (CF#337)

WATER METAL RESULTS

(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As ICP-MS	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVAA	Pb ICP-MS
STANDARD REFERENCE MATERIAL											
1643b REP 1 (SRM 4)	certified value	19.9 18.6 ±0.4	42.9 49 ±3	21 21.9 ±0.4	63 66 ±2	53.5 NC NC		9.68 9.8 ±0.8	18.9 20 ±1	NA NA NA	21.6 23.7 ±0.7
1643b REP 2 (SRM 5)	certified value	17.6 18.6 ±0.4	41.6 49 ±3	20 21.9 ±0.4	59.9 66 ±2	55.1 NC NC		9.54 9.8 ±0.8	18.9 20 ±1	NA NA NA	23.8 23.7 ±0.7
1643b REP 3 (SRM 6)	certified value	18.1 18.6 ±0.4	44.8 49 ±3	21.2 21.9 ±0.4	60.3 66 ±2	56.9 NC NC		9.99 9.8 ±0.8	20.1 20 ±1	NA NA NA	24.8 23.7 ±0.7
1643b REP 4 (SRM 7)	certified value	18.2 18.6 ±0.4	42.3 49 ±3	20.9 21.9 ±0.4	64 66 ±2	59.3 NC NC		9.77 9.8 ±0.8	20 20 ±1	NA NA NA	24.7 23.7 ±0.7
1643b REP 5 (SRM 8)	certified value	21.4 18.6 ±0.4	49.8 49 ±3	23.6 21.9 ±0.4	68.7 66 ±2	84 NC NC		9.99 9.8 ±0.8	20 20 ±1	NA NA NA	20.8 23.7 ±0.7
1641b	certified value	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	1.48 1.52 ±0.04	NA NA NA

NA = Not applicable.

NC = Not certified.

337 METALS DATA

8/21/91

OAKLAND INNER (BRANNON) (CF#337)

WATER METAL RESULTS

(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As ICP-MS	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVAA	Pb ICP-MS
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MATRIX SPIKE RESULTS

Amount Spiked	20	20	20	20	20	20	20	100	1	0.05	5
337-81 + Spike	57.2	62.5	71.3	134	31.6	53.3	1.71	0.04153	0.63	0.00242	34.5
337-81	30.8	42.3	50.4	103	7.3	1.09	0.03911	52.21	1.08	0.03911	25.9
Amount Recovered	26.4	20.2	20.9	31	24.3	52.21	108%	78%			8.6
Percent Recovered	132%	101%	105%	155%	122%	52%					172%
Amount Spiked	20	20	20	20	20	20	20	100	1	0.05	5
337-94 + Spike	29.1	28.5	32.6	40.5	32	55.9	1.24	0.04594	0.15	0.00199	12.9
337-94	10.5	11.4	16.5	22.5	12.3	1.17	0.03911	54.73	1.09	0.04395	7.72
Amount Recovered	18.6	17.1	16.1	18	19.7	55%	109%				5.18
Percent Recovered	93%	86%	81%	90%	99%						104%

9/4/91

WES OAKLAND INNER (BRANNON) (CF #337)

**ORGANOTIN ANALYSIS
OF WATER SAMPLES**

MSL Code	Sponsor Code	(concentrations in ng/L)				
		Tripentyl % Surrogate	Tetra Tin	Tributyl Tin	Dibutyl Tin	Monobutyl Tin
337-1	OIAS-TBT-D1-1	100.95	3.9 U	6.0	21.4 B	12.0 B
337-2	OIAS-TBT-D1-2	99.15	3.5 U	4.4	18.1 B	9.7 B
337-3	OIAS-TBT-D1-3	99.83	2.2 U	10.7	49.3 B	13.0 B
337-4	OIAS-TBT-D2-1	94.71	2.2 U	6.7	16.0 B	13.7 B
337-5	OIAS-TBT-D2-2	88.08	2.0 U	2.3	14.5 B	9.8 B
337-6	OIAS-TBT-D2-3	75.80	1.8 U	5.9	10.9 B	13.2 B
337-7	OIAS-TBT-D3-1	81.36	2.5 U	13.1	16.2 B	14.7 B
337-8	OIAS-TBT-D3-2	109.51	2.7 U	33.6	40.1 B	18.1 B
337-9	OIAS-TBT-D3-3	104.96	1.9 U	5.4	8.5 B	8.1 B
337-10	OIAS-TBT-D4-1	99.83	2.4 U	4.3	9.3 B	5.7 B
337-11	OIAS-TBT-D4-2	87.87	3.2 U	3.7	11.4 B	12.2 B
337-12	OIAS-TBT-D4-3	85.98	2.7 U	2.9 U	7.7 B	9.1 B
337-13	OIAS-TBT-D5-1	76.06	1.8 U	3.8	14.2 B	20.5 B
337-14	OIAS-TBT-D5-2	86.95	2.0 U	6.0	13.6 B	11.2 B
337-15	OIAS-TBT-D5-3	91.18	3.1 U	3.4 U	8.4 B	6.1 B
337-16	OIAS-TBT-D6-1	85.05	2.0 U	6.0	11.4 B	7.8 B
337-17	OIAS-TBT-D6-2	60.60	2.3 U	2.8 U	5.7 B	5.9 B
337-18	OIAS-TBT-D6-3	92.60	2.5 U	2.8 U	4.2 B	4.9 B
337-19	OIAS-TBT-H2O BLK	71.61	2.6 U	2.8 U	4.2 B	4.9 B
337-20	OOAS-TBT-D1-1	90.98	2.5 U	43.0	32.5 B	16.8 B
337-21	OOAS-TBT-D1-2	101.50	2.7 U	50.7	30.2 B	34.8 B
337-22	OOAS-TBT-D1-3	98.17	2.2 U	58.6	31.8 B	17.3 B
337-23	OOAS-TBT-D2-1	105.69	2.2 U	37.3	28.1 B	13.7 B
337-24	OOAS-TBT-D2-2	96.26	2.2 U	41.5	29.3 B	17.6 B
337-25	OOAS-TBT-D2-3	103.24	2.7 U	49.7	33.8 B	35.6 B
337-26	OOAS-TBT-D3-1	93.72	2.6 U	36.8	17.9 B	19.6 B
337-27	OOAS-TBT-D3-2	93.23	2.7 U	17.7	13.7 B	12.2 B
337-28	OOAS-TBT-D3-3	92.08	2.0 U	28.3	32.4 B	20.9 B
337-29	OOAS-TBT-D4-1	84.89	2.6 U	23.5	12.7 B	8.0 B
337-30	OOAS-TBT-D4-2	91.60	2.0 U	13.5	11.7 B	12.8 B
337-31	OOAS-TBT-D4-3	90.42	2.4 U	10.1	11.0 B	4.9 B
337-32	OOAS-TBT-D5-1	77.85	2.8 U	13.3	8.5 B	14.4 B
337-33	OOAS-TBT-D5-2	73.01	2.5 U	13.7	11.0 B	4.9 B
337-34	OOAS-TBT-D5-3	77.52	2.6 U	9.9	23.4 B	23.8 B
337-35	OOAS-TBT-D6-1	74.05	2.9 U	20.2	10.6 B	17.9 B
337-36	OOAS-TBT-D6-2	92.87	2.3 U	8.4	11.3 B	16.2 B
337-37	OOAS-TBT-D6-3	88.70	2.5 U	9.6	9.6 B	15.6 B
337-38	OOAS-TBT-H2O BLK	79.25	3.0 U	3.5 U	3.1 U	4.7 B

B = Indicated analyte detected in method blank associated with the sample. Data is not blank corrected.

U = Indicates analyte not detected above detection limits.

9/4/91

WES OAKLAND INNER (BRANNON) (CF #337)

**ORGANOTIN ANALYSIS
OF WATER SAMPLES**

(concentrations in ng/L)

MSL Code	Sponsor Code	Tripentyl % Surrogate	Tetra Tin	Tributyl Tin	Dibutyl Tin	Monobutyl Tin
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METHOD BLANK RESULTS

337-BLANK-1	100.95	2.6 U	2.9 U	4.6	4.2
337-BLANK-2	85.66	2.7 U	3 U	4.3	12.1
337-BLANK-3	86.33	2.5 U	2.9 U	3.1	6.7
337-BLANK-4	90.46	3 U	3.5 U	3.1 U	4.7

BLANK AND MATRIX SPIKE RECOVERIES

337-1-SPIKE	102.44	98.2	152.6	157.9	91.8
% Recovery		47.15%	73.30%	68.25%	39.90%
337-14-SPIKE	89.15	36.1	101.9	160.4	83.2
% Recovery		17.05%	47.95%	73.40%	36.00%
337-27 SPIKE	92.13	82.6	207.1	240.5	125.9
% Recovery		23.99%	56.88%	68.11%	34.14%
337-36-SPIKE	87.99	66.3	142.2	169.1	96.7
% Recovery		32.0%	66.9%	8.9%	40.25%

PAH WATER CONCENTRATIONS
(concentrations in ng/L, ppb)

SPONSOR CODE:		METHOD BLANK		OIAS-PAH-BLANK		D1-OIAS-#1		D1-OIAS-#2		D1-OIAS-#3		D2-OIAS-#1	
Sample ID	Sample Volume(L)	1.000	337-39	337-40	337-41	337-42	337-43	1.000	1.000	1.000	1.075	1.075	1.075
naphthalene		4.02 J	53.07	26.24	26.76	22.72	27.31						
acenaphthylene		9.17 U	9.17 U	9.17 U	9.17 U	9.17 U	2.88 J						
acenaphthene		5.87 U	5.87 U	5.87 U	5.87 U	5.87 U	5.37 U						
fluorene		6.89 U	4.32 J	2.93 J	2.46 J	2.60 J	2.32 J						
phenanthrene		7.82 U	18.99	6.50 J	4.79 J	4.56 J	3.15 J						
anthracene		11.50 U	11.50 U	1.81 J	2.42 J	11.50 U	11.50 U						
fluoranthene		5.91 U	2.49 J	5.92	3.56 J	5.40 J	2.15 J						
pyrene		6.53 U	6.53 U	18.14	12.23	15.23	6.84						
benz[a]anthracene		30.02 U	30.02 U	30.02 U	30.02 U	30.02 U	30.02 U						
chrysene		19.20 U	19.20 U	19.20 U	19.20 U	19.20 U	19.20 U						
benzo[b]fluoranthene		14.67 U	14.67 U	14.67 U	14.67 U	14.67 U	14.67 U						
benzo[k]fluoranthene		13.34 U	13.34 U	13.34 U	13.34 U	13.34 U	13.34 U						
benzo[a]pyrene		6.39 U	6.39 U	6.39 U	6.39 U	6.39 U	6.39 U						
indeno[1,2,3-c,d]pyrene		20.67 U	20.67 U	20.67 U	20.67 U	20.67 U	20.67 U						
dibenz[a,h]anthracene		21.55 U	21.55 U	21.55 U	21.55 U	21.55 U	21.55 U						
benzo[g,h,i]perylene		19.96 U	19.96 U	19.96 U	19.96 U	19.96 U	19.96 U						
Surrogate Recoveries													
naphthalene-d8(% Rec)		85	89	88	93	80	85						
acenaphthene-d10(% Rec)		85	105	105	100	90	98						
benzo[a]pyrene-d12(% Rec)		91	93	94	90	78	87						

J - Value below MDL.

U - Not detected, replaced with MDL.

& - Surrogate Recovery out of Range.

PAH WATER CONCENTRATIONS
(concentrations in ng/L, ppb)

SPONSOR CODE:

Sample ID

Sample Volume(L)

	D2-OIAS-#2 337-44	D2-OIAS-#3 337-45	D3-OIAS-#1 337-46	D3-OIAS-#2 337-47	D3-OIAS-#3 337-48	D4-OIAS-#1 337-49	D4-OIAS-#2 337-50
	0.890	0.880	0.825	0.920	0.805	0.760	0.740
naphthalene	32.05	34.08	42.08	35.62	33.84	38.79	35.27
acenaphthylene	9.17 U	9.17 U	9.17 U	2.78 J	2.84 J	3.55 J	3.88 J
acenaphthene	5.87 U	5.87 U	5.87 U	5.87 U	5.07 J	4.21 J	4.32 J
fluorene	2.31 J	1.80 J	3.36 J	3.82 J	3.80 J	5.81 J	4.51 J
phenanthrene	3.77 J	3.82 J	4.27 J	5.74 J	5.75 J	7.52 J	6.35 J
anthracene	11.50 U	11.50 U	11.50 U	11.50 U	11.50 U	11.50 U	11.50 U
fluoranthene	2.43 J	2.68 J	1.87 J	3.32 J	2.89 J	2.76 J	4.38 J
pyrene	7.52	10.01	4.71 J	10.00	8.60	7.10	13.55
benz[a]anthracene	30.02 U	30.02 U	30.02 U	30.02 U	30.02 U	30.02 U	0.89 J
chrysene	19.20 U	19.20 U	19.20 U	19.20 U	19.20 U	19.20 U	1.70 J
benzo[b]fluoranthene	14.67 U	14.67 U	14.67 U	14.67 U	14.67 U	14.67 U	1.51 J
benzo[k]fluoranthene	13.34 U	13.34 U	13.34 U	13.34 U	13.34 U	13.34 U	0.63 J
benzo[a]pyrene	6.39 U	6.39 U	6.39 U	6.39 U	6.39 U	6.39 U	0.58 J
indeno[1,2,3-c,d]pyrene	20.67 U	20.67 U	20.67 U	20.67 U	20.67 U	20.67 U	20.67 U
dibenz[a,h]anthracene	21.55 U	21.55 U	21.55 U	21.55 U	21.55 U	21.55 U	21.55 U
benzo[g,h,i]perylene	19.96 U	19.96 U	19.96 U	19.96 U	19.96 U	19.96 U	19.96 U

Surrogate Recoveries

naphthalene-d8(% Rec)	86
acenaphthene-d10(% Rec)	94
benzo[a]pyrene-d12(% Rec)	87

J - Value below MDL.

U - Not detected, replaced with MDL.

& - Surrogate Recovery out of Range.

PAH WATER CONCENTRATIONS
(concentrations in ng/L, ppb)

SPONSOR CODE:

Sample ID

Sample Volume(L)

	D4-OIAS-#3 337-51	D5-OIAS-#1 337-52	D5-OIAS-#2 337-53	D5-OIAS-#3 337-54	D6-OIAS-#1 337-55	D6-OIAS-#2 337-56	D6-OIAS-#3 337-57
	0.700	0.790	0.840	0.810	0.920	1.010	0.940
naphthalene	18.78	38.13	44.13	38.45	41.56	49.04	54.31
acenaphthylene	3.29 J	9.17 U	9.17 U	9.17 U	9.17 U	9.17 U	9.17 U
acenaphthone	5.71 J	3.84 J	5.37 J	3.08 J	4.27 J	5.07 J	4.87 J
fluorene	4.50 J	2.85 J	2.61 J	3.25 J	2.53 J	2.89 J	3.27 J
phenanthrene	5.71 J	3.71 J	9.32	3.90 J	4.45 J	4.04 J	5.06 J
anthracene	11.50 U	11.50 U	11.50 U	11.50 U	11.50 U	11.50 U	11.50 U
fluoranthene	3.53 J	1.74 J	2.67 J	2.32 J	2.37 J	3.20 J	4.07 J
pyrene	10.43	4.20 J	4.52 J	4.74 J	4.66 J	7.97	6.10 J
benz[a]anthracene	30.02 U	30.02 U	30.02 U	30.02 U	30.02 U	30.02 U	30.02 U
chrysene	19.20 U	19.20 U	19.20 U	1.39 J	19.20 U	0.56 J	19.20 U
benzo[b]fluoranthene	14.67 U	14.67 U	14.67 U	14.67 U	14.67 U	14.67 U	14.67 U
benzo[k]fluoranthene	13.34 U	13.34 U	13.34 U	13.34 U	13.34 U	13.34 U	13.34 U
benzo[a]pyrene	6.39 U	6.39 U	6.39 U	6.39 U	6.39 U	6.39 U	6.39 U
indeno[1,2,3-c,d]pyrene	20.67 U	20.67 U	20.67 U	20.67 U	20.67 U	20.67 U	20.67 U
dibenz[a,h]anthracene	21.55 U	21.55 U	21.55 U	21.55 U	21.55 U	21.55 U	21.55 U
benzo[g,h,i]perylene	19.96 U	19.96 U	19.96 U	19.96 U	19.96 U	19.96 U	19.96 U

Surrogate Recoveries

naphthalene-d8(% Rec)	70	97	98	98	90	92	93
acenaphthene-d10(% Rec)	93	98	99	97	96	93	97
benzo[a]pyrene-d12(% Rec)	88	68	84	49	53	66	73

J - Value below MDL.

U - Not detected, replaced with MDL.

& - Surrogate Recovery out of Range.

PAH WATER CONCENTRATIONS (continued)
(concentrations in ng/L, ppb)

SPONSOR CODE: Sample ID	METHOD/BLANK JL39PB	D1-OOAS-#1 337-58	D1-OOAS-#2 337-59	D1-OOAS-#3 337-60	D2-OOAS-#1 337-61	D2-OOAS-#2 337-62
Sample Volume(L)	1.000	1.100	0.800	0.830	0.890	1.000
naphthalene	5.79 J	31.54	36.53	38.38	41.12	33.37
acenaphthylene	9.17 U	9.17 U	9.17 U	9.17 U	9.17 U	9.17 U
acenaphthene	5.87 U	3.22 J	3.09 J	4.10 J	3.97 J	2.23 J
fluorene	6.89 U	3.18 J	3.21 J	4.49 J	4.62 J	4.01 J
phenanthrene	1.46 J	4.82 J	4.29 J	8.35	7.05 J	5.37 J
anthracene	11.50 U	1.86 J	1.68 J	3.23 J	1.18 J	1.12 J
fluoranthene	5.91 U	7.09	5.93	14.95	5.23 J	4.40 J
pyrene	6.53 U	18.87	15.01	40.18	11.09	9.01
benz[a]anthracene	30.02 U	1.82 J	2.25 J	5.02 J	1.86 J	1.70 J
chrysene	19.20 U	2.06 J	1.95 J	6.09 J	1.73 J	0.93 J
benzo[b]fluoranthene	14.67 U	5.48 J	4.15 J	11.81 J	3.71 J	2.00 J
benzo[k]fluoranthene	13.34 U	2.57 J	3.61 J	10.92 J	1.18 J	1.48 J
benzo[a]pyrene	6.39 U	1.89 J	1.40 J	6.26 J	1.56 J	6.39 U
indeno[1,2,3-c,d]pyrene	20.67 U	1.68 J	1.61 J	6.25 J	20.67 U	20.67 U
dibenz[a,h]anthracene	21.55 U	21.55 U	21.55 U	21.55 U	21.55 U	21.55 U
benzo[g,h,i]perylene	19.96 U	19.96 U	1.41 J	5.70 J	19.96 U	19.96 U
naphthalene-d8 (% Rec)	86	81	77	77	82	77
acenaphthene-d10 (% Rec)	85	88	83	84	85	79
benzo[a]pyrene-d12 (% Rec)	78	64	66	68	70	69

J - Value below MDL.
U - Not detected, replaced with MDL.
& - Surrogate Recovery out of Range.

PAH WATER CONCENTRATIONS (continued)
(concentrations in ng/L, ppb)

SPONSOR CODE:		D2-OOAS-#3		D3-OOAS-#1		D3-OOAS-#2		D3-OOAS-#3		D4-OOAS-#1		D4-OOAS-#2		D4-OOAS-#3	
Sample ID		337-63		337-64		337-65		337-66		337-67		337-68		337-69	
Sample Volume(L)		0.820		1.000		0.820		0.710		0.920		0.810		0.680	
naphthalene		33.15		28.21		69.78		43.11		80.97		56.19		38.85	
acenaphthylene		9.17 U		0.82 J		9.17 U		9.17 U		9.17 U		9.17 U		9.17 U	
acenaphthene		2.88 J		1.96 J		5.87 U		1.53 J		3.22 J		5.87 U		1.89 J	
fluorene		2.23 J		3.22 J		6.89 U		2.23 J		3.21 J		2.94 J		3.16 J	
phenanthrene		3.55 J		5.72 J		4.90 J		4.28 J		3.72 J		4.11 J		3.87 J	
anthracene		0.61 J		0.73 J		11.50 U		0.45 J		0.66 J		11.50 U		11.50 U	
fluoranthene		3.06 J		3.51 J		2.73 J		2.40 J		2.49 J		2.73 J		2.23 J	
pyrene		6.89		6.15 J		3.93 J		4.31 J		4.06 J		5.16 J		4.19 J	
benz[a]anthracene		30.02 U		30.02 U		30.02 U		30.02 U		30.02 U		30.02 U		30.02 U	
chrysene		19.20 U		19.20 U		19.20 U		19.20 U		19.20 U		19.20 U		19.20 U	
benzo[b]fluoranthene		14.67 U		14.67 U		14.67 U		14.67 U		14.67 U		14.67 U		14.67 U	
benzo[k]fluoranthene		13.34 U		13.34 U		13.34 U		13.34 U		13.34 U		13.34 U		13.34 U	
benzo[a]pyrene		6.39 U		6.39 U		6.39 U		6.39 U		6.39 U		6.39 U		6.39 U	
indeno[1,2,3-c,d]pyrene		20.67 U		20.67 U		20.67 U		20.67 U		20.67 U		20.67 U		20.67 U	
dibenz[a,h]anthracene		21.55 U		21.55 U		21.55 U		21.55 U		21.55 U		21.55 U		21.55 U	
benzo[g,h,i]perylene		19.96 U		19.96 U		19.96 U		19.96 U		19.96 U		19.96 U		19.96 U	
naphthalene-d8 (% Rec)		75		85		92		89		94		96		89	
acenaphthene-d10 (% Rec)		76		84		92		91		98		94		87	
benzo[a]pyrene-d12 (% Rec)		62		73		70		76		80		70		76	

J - Value below MDL.

U - Not detected, replaced with MDL.

& - Surrogate Recovery out of Range.

PAH WATER CONCENTRATIONS (continued)
(concentrations in ng/L, ppb)

SPONSOR CODE:		D5-OOAS-#1	D5-OOAS-#2	D5-OOAS-#3	D6-OOAS-#1	D6-OOAS-#2	D6-OOAS-#3	OOAS-PAH-BLANK
Sample ID	337-70	337-71	337-72	337-73	337-74	337-75	337-76	
Sample Volume(L)	0.800	0.850	0.810	0.960	0.940	0.815	0.970	
naphthalene	28.93	49.75	43.20	21.33	28.80	32.06	38.64	
acenaphthylene	9.17 U	9.17 U	9.17 U	9.17 U	9.17 U	9.17 U	33.97	
acenaphthene	2.72 J	3.50 J	5.87 U	2.22 J	2.52 J	2.56 J	9.17	
fluorene	4.59 J	4.00 J	6.89 U	4.42 J	3.48 J	2.96 J	27.94	
phenanthrene	7.03 J	4.88 J	4.25 J	5.91 J	3.96 J	3.43 J	121.28	
anthracene	11.50 U	11.50 U	11.50 U	11.50 U	0.68 J	0.63 J	11.50 U	
fluoranthene	3.88 J	3.36 J	5.91 U	3.86 J	2.84 J	2.70 J	10.87	
pyrene	4.91 J	5.42 J	4.66 J	4.78 J	3.22 J	3.46 J	4.18 J	
benz[a]anthracene	30.02 U	30.02 U	30.02 U	30.02 U	30.02 U	30.02 U	30.02 U	
chrysene	19.20 U	19.20 U	19.20 U	19.20 U	19.20 U	19.20 U	0.73 J	
benzo[b]fluoranthene	14.67 U	14.67 U	14.67 U	14.67 U	14.67 U	14.67 U	14.67 U	
benzo[k]fluoranthene	13.34 U	13.34 U	13.34 U	13.34 U	13.34 U	13.34 U	13.34 U	
benzo[a]pyrene	6.39 U	6.39 U	6.39 U	6.39 U	6.39 U	6.39 U	6.39 U	
indeno[1,2,3-c,d]pyrene	20.67 U	20.67 U	20.67 U	20.67 U	20.67 U	20.67 U	20.67 U	
dibenz[a,h]anthracene	21.55 U	21.55 U	21.55 U	21.55 U	21.55 U	21.55 U	21.55 U	
benzo[g,h,i]perylene	19.96 U	19.96 U	19.96 U	19.96 U	19.96 U	19.96 U	19.96 U	
naphthalene-d8 (% Rec)	95	83	88	86	89	90	69	
acenaphthene-d10 (% Rec)	90	78	87	85	84	91	68	
benzo[a]pyrene-d12 (% Rec)	79	70	77	68	77	77	73	

J - Value below MDL.

U - Not detected, replaced with MDL.

& - Surrogate Recovery out of Range.

PAH WATER BLANK SPIKE RESULTS

(CF# 310 and 337)

CP# 310 and 337

Sample ID:	Amount Spiked (ng/L)	Amounts Recovered (ng/L)		PERCENT RECOVERIES		
		MS	MSD	MS	MSD	%RPD
Analyte						
naphthalene	248.25	263.59	261.84	106%	105%	1%
acenaphthylene	238.50	245.75	236.63	103%	99%	4%
acenaphthene	257.25	267.87	265.07	104%	103%	1%
fluorene	245.25	265.74	247.59	108%	101%	7%
phenanthrene	248.25	293.72	261.13	118%	105%	12%
anthracene	187.50	211.45	185.98	113%	99%	13%
fluoranthene	246.75	299.10	244.93	121%	99%	20%
pyrene	248.25	316.86	259.03	128%	104%	20% &
benz[a]anthracene	213.00	320.26	241.73	150% &	113%	28% &
chrysene	248.25	409.87	317.89	165%	128%	25% &
benzo[b]fluoranthene	246.75	217.00	202.05	88%	82%	7%
benzo[k]fluoranthene	246.75	250.08	245.87	101%	100%	2%
benzo[a]pyrene	223.50	215.64	211.73	96%	95%	2%
indeno[1,2,3-c,d]pyrene	219.75	188.95	179.93	86%	82%	5%
dibenz[a,h]anthracene	187.50	150.88	141.90	80%	76%	6%
benzo[g,h,i]perylene	219.75	193.02	191.27	88%	87%	1%
Surrogates						
naphthalene-d8 (% Rec)	250.50	214.22	229.55	86%	92%	7%
acenaphthene-d10 (% Rec)	249.50	212.33	239.11	85%	96%	12%
benzo[a]pyrene-d12 (% Rec)	250.00	244.07	260.96	98%	104%	7%

$$\%RPD = [2 \cdot ((X1 - X2) / (X1 + X2)) \cdot 100]$$

& - Value out of specified criteria.

PAH WATER BLANK SPIKE RESULTS

(CF# 310 and 337)

Sample ID:	Amount Spiked (ng/L)	Amounts Recovered (ng/L)		PERCENT RECOVERIES		
		MS	MSD	MS	MSD	%RPD
<u>Analyte</u>						
naphthalene	248.25	269.60	266.51	109%	107%	1%
acenaphthylene	238.50	248.43	226.51	104%	95%	9%
acenaphthene	257.25	281.69	279.51	110%	109%	1%
fluorene	245.25	265.08	257.02	108%	105%	3%
phenanthrene	248.25	258.04	258.35	104%	104%	0%
anthracene	187.50	190.83	181.68	102%	97%	5%
fluoranthene	246.75	238.75	236.09	97%	96%	1%
pyrene	248.25	245.01	245.46	99%	99%	0%
benz[a]anthracene	213.00	194.37	201.62	91%	95%	4%
chrysene	248.25	238.01	259.15	96%	104%	9%
benzo[b]fluoranthene	246.75	284.03	269.97	115%	109%	5%
benzo[k]fluoranthene	246.75	270.97	277.87	110%	113%	3%
benzo[a]pyrene	223.50	225.81	232.62	101%	104%	3%
indeno[1,2,3-c,d]pyrene	219.75	188.28	205.96	86%	94%	9%
dibenz[a,h]anthracene	187.50	156.91	167.37	84%	89%	6%
benzo[g,h,i]perylene	219.75	184.92	206.48	84%	94%	11%
Surrogates						
naphthalene-d8 (% Rec)	250.50	222.81	153.08	89%	61%	37%
acenaphthene-d10 (% Rec)	249.50	228.50	148.79	92%	60%	42%
benzo[a]pyrene-d12 (% Rec)	250.00	214.63	131.24	86%	52%	48%

%RPD = $[2 * ((X1 - X2) / (X1 + X2)) * 100]$
 & - RPD outside acceptance criteria

PAH WATER BLANK SPIKE RESULTS

(CF# 310 and 337)

Sample ID:	Amount Spiked (ng/L)	Amounts Recovered (ng/L)		PERCENT RECOVERIES		
		MS	MSD	MS	MSD	%RPD
<u>Analyte</u>						
naphthalene	248.25	275.19	266.57	111%	107%	3%
acenaphthylene	238.50	232.55	205.15	98%	86%	13%
acenaphthene	257.25	281.03	283.59	109%	110%	1%
fluorene	245.25	271.60	265.68	111%	108%	2%
phenanthrene	248.25	273.81	272.55	110%	110%	0%
anthracene	187.50	191.84	175.11	102%	93%	9%
fluoranthene	246.75	241.32	220.90	98%	90%	9%
pyrene	248.25	253.12	234.07	102%	94%	8%
benz[a]anthracene	213.00	186.30	163.37	87%	77%	13%
chrysene	248.25	224.77	236.49	91%	95%	5%
benzo[b]fluoranthene	246.75	254.87	297.99	103%	121%	16%
benzo[k]fluoranthene	246.75	310.05	285.57	126%	116%	8%
benzo[a]pyrene	223.50	247.87	233.22	111%	104%	6%
indeno[1,2,3-c,d]pyrene	219.75	171.21	176.82	78%	80%	3%
dibenz[a,h]anthracene	187.50	147.61	151.82	79%	81%	3%
benzo[g,h,i]perylene	219.75	174.78	186.97	80%	85%	7%
Surrogates						
naphthalene-d8 (% Rec)	250.50	212.66	223.91	87%	89%	2%
acenaphthene-d10 (% Rec)	249.50	223.01	214.59	89%	86%	4%
benzo[a]pyrene-d12 (% Rec)	250.00	220.49	203.55	88%	81%	8%

$$\%RPD = [2*((X1-X2)/(X1+X2))*100]$$

9/12/91

WES OAKLAND (BRANNON/PRICE) (CF #321)

WATER METAL RESULTS

(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Salinity (ppt)	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As AA	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVA	Pb ICP-MS
321-1	IOM-10-1	16	186	950	55.8	248	10.30		0.24	0.92	0.21678	4.18
321-2	IOM-10-2	15	262	1070	1.96	107	16.57		0.37	0.02	0.01553	2.08
321-3 rep 1	IOM-10-3	13	331	1400	0.1 U	74.2	25.09		0.32	0.01 U	0.01029	1.83
321-3 rep 2	IOM-10-3	NA	335	1400	0.1 U	56.5	23.74		0.82	0.01 U	NA	1.24
321-4	IOM-10-4	10	286	1230	0.1 U	87.5	30.46		0.68	0.01 U	0.00837	1.38
321-5	IOM-10-5	14	259	1190	1.87	35.9	33.15		0.23	0.12	0.01032	1.59
321-6	IOM-10-6	13	262	1060	0.1 U	398	28.67		0.35	0.11	0.01500	1.90
321-7	IOM-10-7	16	343	1010	0.50	16	23.74		0.52	0.04	0.01154	1.86
321-8	IOM-10-8	4	319	932	0.37	25.6	21.05		0.05	0.08	0.00663	0.22
321-9	IOM-10-9	2	46.2	519	2.39	15.3	17.02		0.06	0.05	0.00227	1.30
321-10	IOM-11-1	12	146	735	25.3	248	5.38		0.80	0.78	0.02062	3.60
321-11	IOM-11-2	15	225	731	0.1 U	84.3	14.33		0.30	0.17	0.01099	1.56
321-12	IOM-11-3	10	230	804	0.1 U	121	16.57		0.22	0.30	0.00061	1.22
321-13	IOM-11-4	15	250	800	0.1 U	90.5	20.61		0.25	0.01 U	0.00051	1.12
321-14	IOM-11-5	7	334	792	13.2	63.8	14.33		0.05	0.07	0.00637	1.38
321-15	IOM-11-6	10	271	775	16.5	69.5	11.20		0.25	0.10	0.01227	4.84
321-16	IOM-11-7	5	301	823	0.78	55.7	7.62		0.06	0.03	0.00679	0.33
321-17	IOM-12-1	19	364	5040	17.6	223	2.06 U		3.65	1.00	0.36785	4.45
321-18	IOM-12-2	14	400	2660	0.1 U	142	3.58		0.21	0.49	0.01464	1.66
321-19	IOM-12-3	11	561	2140	0.1 U	121	6.27		0.22	0.58	0.01260	1.41
321-20	IOM-12-4	8	439	1530	0.72	112	7.17		0.05	0.32	0.01619	0.36
321-21	IOM-12-5	6	647	1680	0.46	99.2	6.72		0.06	0.27	0.00700	0.16
321-22	IOM-12-6	5	756	1580	1.26	96.9	6.72		0.08	0.26	0.01006	0.23
321-23 rep 1	IOM-10-10	1	37.5	284	6.02	8.32	8.07		0.06	0.01	0.00192	2.43
321-23 rep 2	IOM-10-10	NA	38.9	292	5.27	9.69	8.51		0.04	0.01 U	NA	2.53
321-24	IOM-10-11	2	19.8	252	7.88	14.8	13.44		0.04	0.01 U	0.00420	4.42
321-25	IOM-10-12	1	9.69	31.4	16.5	28.8	11.20		0.05	0.17	0.00181	10.8
321-26	IOM-10-13	6	31.1	39.9	30.9	45.7	13.44		0.11	0.15	0.01573	14.1
321-27	IOM-10-14	6	55.0	59.4	53.5	81.3	11.20		0.17	0.25	0.01347	26.9
321-28	IOM-10-15	5	68.9	77.6	57.7	91.4	8.51		0.18	0.32	0.00864	23.4
321-29	IOM-10-16	1	11.7	24.5	16.5	68.2	10.30		0.02	0.15	0.00105	23.8
321-30	IOM-10-17	4	43.2	54	36.8	124	12.09		0.06	0.34	0.00621	39.8
321-31	IOM-10-18	4	95.8	123	93.5	150	6.27		0.22	0.39	0.00719	40.3
321-32	IOM-10-19	6	113	133	97.0	159	6.72		0.29	0.49	0.01256	44.1
321-33	IOM-10-20	3	15.0	22.2	36.3	55.0	8.51		0.04	0.19	0.00535	23.2
321-34	IOM-10-21	0	6.91	8.53	22.7	14.5	8.06		0.04	0.08	0.00820	11.4
321-35	IOM-10-22	16	44.6	46.2	44.6	30.7	10.30		0.46	1.42	0.01667	16.8
321-36	IOM-10-23	5	7.09	9.44	20.2	23.5	10.75		0.06	0.12	0.00342	9.56
321-37	IOM-10-24	4	27.8	35.9	52.8	48.3	8.96		0.09	0.21	0.00361	13.4
321-38	IOM-11-8	4	343	924	2.86	53.0	5.38		0.12	0.08	0.00866	0.27

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WES OAKLAND (BRANNON/PRICE) (CF #321)

WATER METAL RESULTS

(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Salinity (ppt)	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As AA	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVA	Pb ICP-MS
321-39	IOM-11-9	4	378	973	2.83	48.8	5.38		0.17	0.28	0.01029	0.69
321-40	IOM-11-10	3	309	767	2.36	47.0	9.41		0.06	0.10	0.00607	0.61
321-41	IOM-11-11	10	489	956	8.57	38.9	11.65		0.27	0.30	0.00612	0.43
321-42	IOM-11-12	3	445	847	3.15	52.4	10.30		0.06	0.08	0.00825	0.22
321-43	IOM-11-13	3	289	667	2.65	45.9	11.65		0.04	0.17	0.00687	0.96
321-44	IOM-11-14	3	117	450	4.82	12.1	10.30		0.06	0.09	0.00715	0.44
321-45	IOM-11-15	3	76.8	530	3.35	10.9	10.75		0.11	0.18	0.00773	0.46
321-46 Rep 1	IOM-11-16	6	25.0	424	6.22	10.5	13.44		0.04	0.13	0.01295	0.73
321-46 Rep 2	IOM-11-16		28.5	459	5.56	NA	13.44		0.05	0.18	NA	0.85
321-47	IOM-11-17	NA	15.5	389	14.5	17.7	13.44		0.04	0.17	0.01170	2.05
321-48	IOM-11-18	0	8.81	208	16.2	17.1	15.23		0.06	0.08	0.00655	2.74
321-49	IOM-11-19	23	50.2	187	52.2	33.2	14.33		0.64	0.48	0.07390	10.7
321-50	IOM-11-20	0	12.6	116	38.1	36.4	6.27		0.07	0.13	0.00723	11.3
321-51	IOM-11-21	0	15.9	95.9	46.7	50.6	2.24		0.05	0.12	0.00628	20.2
321-52	IOM-12-7	4	569	1370	1.33	76.6	5.99		0.03	0.27	0.01562	0.13
321-53	IOM-12-8	4	396	1270	0.50	70.3	6.49		0.07	0.41	0.00845	0.41
321-54	IOM-12-9	4	330	1230	0.61	66.9	7.98		0.06	0.24	0.00665	0.19
321-55	IOM-12-10	11	336	1270	43.6	77.7	2.49		0.32	0.21	0.00498	2.02
321-56	IOM-12-11	3	532	1390	2.17	71.1	4.99		0.07	0.22	0.00622	0.25
321-57	IOM-12-12	1	2.43	1300	0.96	22.0	0.86 U		0.05	0.18	0.00044 U	0.19
321-58	IOM-12-13	1	68.1	1390	0.67	30.3	0.86 U		0.04	0.11	0.00044 U	0.02
321-59	IOM-12-14	3	618	1470	0.5 U	77.5	4.49		0.09	0.22	0.00567	0.18
321-60	IOM-12-15	1	3.14	1220	0.5 U	16.5	0.86 U		0.04	0.12	0.00050	0.05
321-61	IOM-12-16	5	465	1390	0.66	41.6	10.98		0.05	0.17	0.00540	0.24
321-62	IOM-12-17	3	417	1260	5.65	34.5	7.98		0.05	0.22	0.00355	0.41
321-63	IOM-12-18	1	0.39	1230	0.1 U	9.07	0.86 U		0.01 U	0.01 U	0.00038	0.05
321-64	IOM-12-19	33	422	1120	0.1 U	30.8	3.99		0.16	0.01 U	0.00786	0.77
321-65	IOM-12-20	2	393	1130	0.1 U	33.9	4.49		0.01	0.09	0.02170	0.22
321-66	IOM-12-21	6	434	923	0.23	22.0	3.99		0.06	0.07	0.06550	0.31
321-67	IOM-12-22	5	255	625	0.69	14.9	6.49		0.03	0.23	0.06790	0.78
321-68	OOM-1-1	24	591	1540	0.1 U	83.9	69.84		0.90	0.47	0.00746	3.81
321-69 rep 1	OOM-1-2	17	162	1160	0.1 U	42.7	62.36		1.95	0.01 U	0.06674	1.91
321-69 rep 2	OOM-1-2	NA	148	1070	0.1 U	23.7	62.86		0.01 U	0.29	NA	1.35
321-70	OOM-1-3	13	49.1	286	6.21	14.9	43.40		0.06	0.01 U	0.07274	0.78
321-71	OOM-1-4	10	28.2	49.7	0.94	5 U	45.40		0.01 U	0.01 U	0.06579	0.68
321-72	OOM-1-5	8	36.5	24.4	2.74	53.8	47.89		0.03	0.15	0.04326	0.43
321-73	OOM-1-6	7	52.9	34.6	0.78	8.41	39.41		0.05	0.01 U	0.04592	0.25
321-74	OOM-1-7	8	16.5	8.41	1.47	5.74	43.40		0.01 U	0.01 U	0.04109	0.26
321-75	OOM-1-8	8	14.9	9.62	3.60	6.63	56.87		0.24	0.02	0.01305	0.47
321-76	OOM-1-9	4	13.5	14.9	2.63	10.7	49.39		0.03	0.07	0.04444	0.34

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WES OAKLAND (BRANNON/PRICE) (CF #321)

WATER METAL RESULTS

(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Salinity (pph)	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As AA	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVA	Pb ICP-MS
321-77	OOM-1-10	3	11.9	17.8	1.71	5 U	54.38		0.03	0.08	0.02926	0.74
321-78	OOM-1-11	3	14.0	29.0	4.38	5 U	51.38		0.05	0.01	0.02104	1.74
321-79	OOM-2-1	18	1350	2200	32.7	1010	34.92		0.29	1.17	0.08905	13.6
321-80	OOM-2-2	9	329	868	3.75	796	0.87 U		0.18	0.02	0.06928	0.83
321-81	OOM-2-3	7	237	644	1.77	223	7.48		0.52	0.25	0.06828	0.72
321-82	OOM-2-4	6	158	190	2.22	46.5	22.45		0.06	0.13	0.05246	1.23
321-83	OOM-2-5	7	102	96.4	0.23	19.1	27.44		0.02	0.09	0.06312	1.03
321-84	OOM-2-6	5	111	56.8	1.30	11.5	24.94		0.05	0.18	0.05261	1.86
321-85	OOM-2-7	4	70.1	33.0	0.1 U	7.08	20.45		0.11	0.15	0.03036	0.65
321-86	OOM-2-8	3	51.6	23.4	0.1 U	73.8	21.45		0.01	0.08	0.02252	0.85
321-87	OOM-2-9	3	10.3	8.75	0.1 U	5 U	5.49		0.05	0.01 U	0.02888	0.05
321-88	OOM-2-10	3	10.1	10.4	0.1 U	5 U	4.49		0.13	0.01 U	0.01517	0.05
321-89	OOM-2-11	3	9.20	9.61	0.1 U	5 U	10.98		0.02	0.01 U	0.01582	0.09
321-90	OOM-2-12	3	41.9	10.4	2.88	19.2	20.45		0.05	0.05	0.01855	0.72
321-91	OOM-2-13	5	57.8	13.4	0.66	17.2	22.45		0.04	0.02	0.02577	0.49
321-92	OOM-2-14	7	82.1	11.6	2.69	12.1	31.93		0.18	0.23	0.04172	0.41
321-93	OOM-2-15	10	104	39.6	0.1 U	10.8	28.93		0.27	0.01 U	0.03101	1.55
321-94 rep 1	OOM-3-1	23	64.9	1240	0.1 U	154	1.00		1.67	1.88	0.06544	0.72
321-94 rep 2	OOM-3-1	NA	181	1270	0.1 U	198	0.87 U		1.05	0.93	0.06028	2.65
321-95	OOM-3-2	20	119	339	0.1 U	62.1	57.87		0.94	0.01 U	0.07119	1.39
321-96	OOM-3-3	15	75.6	179	0.1 U	60.4	5.99		0.39	0.01 U	0.06491	1.31
321-97	OOM-3-4	14	74.1	66.9	0.1 U	62.4	25.94		0.29	0.01 U	0.04580	1.72
321-98	OOM-3-5	12	53.7	22.0	0.1 U	38.4	17.46		0.75	0.01 U	0.03284	1.38
321-99	OOM-3-6	10	42.9	7.84	0.1 U	36.7	14.97		0.91	0.01 U	0.02950	0.74
321-100	OOM-3-7	10	43.2	1 U	0.1 U	36.3	24.94		0.78	0.01 U	0.04574	0.51
321-101	OOM-3-8	10	36.8	1 U	0.1 U	40.2	22.95		1.24	0.01 U	0.02642	0.68
321-102	OOM-3-9	8	79.6	29.2	0.63	26.4	29.43		0.32	0.03	0.01500	0.38
321-103	OOM-3-10	5	25.6	3.88	0.1 U	11.5	31.43		0.26	0.01 U	0.01143	0.36
321-104	IOM-11-22	12	55.8	85.9	51.9	85.6	12.47		1.43	0.01 U	0.02110	19.3
321-105	IOM-11-23	2	27.8	59.6	59.9	87.1	12.47		0.19	0.20	0.00656	15.5
321-106	IOM-11-24	3	9.33	33.1	38.7	80.9	15.98		0.05	0.06	0.00258	16.3
321-107	IOM-12-23	14	171	487	0.1 U	5 U	5.49		1.43	0.01 U	0.04994	1.17
321-108	IOM-12-24	2	124	447	1.53	12.4	5.99		0.26	0.04	0.03447	0.96

U = Analyte below detection limits.

NA = Not applicable.

ND = Not detected.

9/12/91

WES OAKLAND (BRANNON/PRICE) (CF #321)

WATER METAL RESULTS

(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Salinity (ppt)	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As AA	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVA	Pb ICP-MS
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STANDARD REFERENCE MATERIAL

SLRS-1, Rep 1			0.37	0.75	2.75	2.63	NA		0.01	0.01 U	NA	0.21
SLRS-1, Rep 2			0.25	0.79	2.66	0.01 U	NA		0.03	0.01 U	NA	0.19
SLRS-1, Rep 3			1.12	2.45	5.68	2.67	NA		0.05	0.09	NA	0.44
SLRS-1, Rep 4			0.69	2.00	3.97	2.05	NA		0.03	0.03	NA	0.14

CERTIFIED
VALUE

			0.36	1.07	3.58	1.34	NA		NC	0.02	NA	0.11
			±0.04	±0.06	±0.3	±0.2	NA		NC	±0.002	NA	±0.001

1643b, Rep 1			18.5	47.3	22.0	66.8	93.11		10.2	19.0	NA	19.7
1643b, Rep 2			19.1	48.9	21.3	72.5	89.22		10.4	20.8	NA	19.4
1643b, Rep 3			19.7	54.3	23.4	69.8	88.51		10.9	21.4	NA	19.7
1643b, Rep 4			17.3	48.8	20.7	63.7	82.09		10.5	19.4	NA	19.2
1643b, Rep 5			18.6	49.5	21.9	75.8	77.70		10.0	19.8	NA	20.1
1643b, Rep 6			18.6	48.7	20.5	79.9	74.63		11.0	20.9	NA	20.6

CERTIFIED
VALUE

			18.6	49.0	21.9	68.0	NC		9.8	20.0	NA	23.7
			±0.4	±3	±0.4	±2	NC		±0.8	±1	NA	±0.7

1641b			NA	NA	NA	NA	NA		NA	NA	1.49	NA
			NA	NA	NA	NA	NA		NA	NA	1.52	NA
			NA	NA	NA	NA	NA		NA	NA	±0.04	NA

U - Analyte below detection limits.
NA - Not applicable.

9/12/91

WES OAKLAND (BRANNON/PRICE) (CF #321)

WATER METAL RESULTS

(concentrations in ug/L (ppb))

Sample Number	Sponsor Code	Salinity (ppt)	Cr ICP-MS	Ni ICP-MS	Cu ICP-MS	Zn ICP-MS	As AA	Se AA	Ag ICP-MS	Cd ICP-MS	Hg CVAA	Pb ICP-MS
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MATRIX SPIKE RESULTS

Amount Spiked			20	20	20	20	21.95		1	1	NS	5
321-7	IOM-10-7		343	1010	0.50	16.0	23.74		0.52	0.04	NS	1.86
321-7+spike			369	1050	19.7	43.9	49.27		2.65	1.15	NS	7.15
Amount Recovered			26.1	40.0	19.2	27.9	25.5		2.1	1.1	NS	5.3
Percent Recovery			131%	200%	96%	140%	116%		213%	110%	NS	106%
Amount Spiked			20	20	20	20	21.95		1	1	0.025000	5
321-25	IOM-10-12		9.7	31.4	16.5	28.8	11.2		0.05	0.17	0.00181	10.8
321-25+spike			27.9	49.6	34.3	54.5	36.73		0.52	1.25	0.02565	15.6
Amount Recovered			18.2	18.2	17.8	25.7	25.5		0.5	1.1	0.02384	4.7
Percent Recovery			91%	91%	89%	128%	116%		48%	108%	95%	95%
Amount Spiked			NS	NS	NS	NS	NS		NS	NS	0.025000	NS
321-46			NS	NS	NS	NS	NS		NS	NS	0.01295	NS
321-46+spike			NS	NS	NS	NS	NS		NS	NS	0.03665	NS
Amount Recovered			NS	NS	NS	NS	NS		NS	NS	0.02370	NS
Percent Recovery			NS	NS	NS	NS	NS		NS	NS	95%	NS
Amount Spiked	*NOTE: HIGH SALINITY		20	20	20	20	21.95		1	1	NS	5
321-49	IOM-11-19		50.2	187	52.2	33.2	14.33		0.64	0.48	NS	10.7
321-49+spike			55.7	287	72.7	45.6	40.32		1.16	1.15	NS	15.5
Amount Recovered			5.5	100.2	20.4	12.4	26.0		0.5	0.7	NS	4.8
Percent Recovery			27%*	501%*	102%	62%	118%		52%	67%	NS	96%
Amount Spiked			20	20	20	20	21.95		1	1	NS	5
321-67	IOM-12-22		255	625	0.69	14.9	6.49		0.03	0.23	NS	0.78
321-67+spike			277	669	21.3	43.2	30.43		0.92	1.43	NS	6.54
Amount Recovered			22.5	43.5	20.6	28.3	23.9		0.9	1.2	NS	5.8
Percent Recovery			113%	217%	103%	141%	109%		89%	119%	NS	115%
Amount Spiked			20	20	20	20	21.95		1	1	0.031385	5
321-93	OOM-2-15		104	39.6	0.10 U	10.8	28.93		0.27	0.01 U	0.03101	1.55
321-93+spike			149	84.2	10.3	57.5	47.39		0.83	1.44	0.05689	6.63
Amount Recovered			44.9	44.6	10.2	46.7	18.5		0.6	1.4	0.02588	1.4
Percent Recovery			224%	223%	51%	234%	84%		57%	143%	82%	143%

NS = Not spiked.

U = Analyte below detection limits.

WES-OAKLAND COLUMN LEACHING (BRANNON)
METALS IN WATER SAMPLES
(CF #354)

11/19/91

(Concentrations in ug/L)

MSL Code	Sponsor ID	Ag ICP/MS	As ICP/MS	Cd ICP/MS	Cr ICP/MS	Cu ICP/MS	Hg CVAA	Ni ICP/MS	Pb ICP/MS	Se ICP/MS	Zn ICP/MS
354-1	OOM-1-12	0.06	76.0	0.22	22.7	9.0	0.00709	24.5	5.3	53.9	11.2
354-2	OOM-1-13	0.06	60.0	0.70	29.6	18.1	0.00243	21.9	10.6	26.0	20.7
354-3	OOM-1-14	0.11	35.7	0.43	32.7	28.8	0.00219	22.3	17.6	20.3	46.5
354-4	OOM-1-15	0.06	29.8	0.59	32.9	39.2	0.01690	24.6	16.0	10.4	35.3
354-5	OOM-1-16	0.06	23.7	0.32	57.8	56.5	0.00090	47.6	24.4	22.5	80.4
354-6	OOM-1-17	0.11	26.3	0.38	30.8	37.4	0.00540	28.3	17.6	3.4	49.5
354-7, Rep 1	OOM-1-18, Rep 1	0.05	23.8	0.12	22.1	26.6	0.00193	20.7	16.9	2.1	40.4
354-7, Rep 2	OOM-1-18, Rep 2	0.04	23.2	0.13	19.6	21.9	0.00222	16.1	17.0	4.8	27.5
354-8	OOM-1-19	0.00	22.2	0.29	27.5	40.1	0.00037	36.4	16.8	3.4	65.4
354-9	OOM-2-16	0.16	82.5	0.57	92.5	1.2	0.00263	46.7	2.0	100.5	4.3
354-10	OOM-2-17	0.06	56.5	0.57	24.4	2.1	0.00229	6.1	1.4	64.6	2.5
354-11	OOM-2-18	0.16	62.0	0.63	18.2	4.0	0.00075	7.6	2.2	51.7	7.0
254-12	OOM-2-19	0.06	47.6	0.11	14.2	12.1	0.00152	11.5	5.6	24.5	11.6
354-13	OOM-2-20	0.06	52.0	0.16	20.4	10.5	0.02328	16.0	6.8	27.5	17.5
354-14	OOM-2-21	0.11	67.5	0.31	32.1	16.8	0.00148	23.5	10.3	52.2	33.9
354-15	OOM-3-11	0.02	33.5	0.13	14.6	2.3	0.00090	4.2	0.9	24.5	3.8
354-16	OOM-3-12	0.04	43.3	0.06	20.8	4.6	0.00113	7.9	1.3	24.8	4.2
354-17	OOM-3-13	0.05	35.5	0.11	19.3	4.1	0.00111	8.2	2.9	16.1	9.1
354-18, Rep 1	OOM-3-14, Rep 1	0.06	55.1	0.55	27.9	10.8	0.00158	7.7	6.0	38.1	16.5
354-18, Rep 2	OOM-3-14, Rep 2	0.06	43.9	0.20	27.4	11.9	0.00145	15.0	6.1	39.1	16.3
354-19	OOM-3-15	0.06	47.2	0.80	31.8	15.4	0.02970	22.7	7.8	27.6	24.6
354-20	OOM-3-16	0.06	43.6	0.25	43.7	16.9	0.00172	30.8	15.8	33.4	30.6
354-21	OOM-3-17	0.06	39.9	0.55	62.0	43.5	0.00250	48.8	26.9	27.7	59.2
354-22	OOM-3-18	0.03	29.9	0.36	29.7	28.9	0.00038	30.7	13.9	9.4	54.9
354-23	OOM-1-20	0.03	22.9	0.28	18.0	25.0	0.00092	19.3	24.3	5.6	49.5
354-24	OOM-1-21	0.08	21.4	0.17	23.2	31.4	0.00304	24.7	16.6	6.2	35.5
354-25	OOM-1-22	0.03	20.4	0.21	14.6	27.9	0.00068	14.1	9.7	6.1	21.9

WES-OAKLAND COLUMN LEACHING (BRANNON)
METALS IN WATER SAMPLES
(CF #354)

11/19/91

(Concentrations in ug/L)

MSL Code	Sponsor ID	Ag ICP/MS	As ICP/MS	Cd ICP/MS	Cr ICP/MS	Cu ICP/MS	Hg CVAA	Ni ICP/MS	Pb ICP/MS	Se ICP/MS	Zn ICP/MS
354-26	OOM-1-23	0.06	22.8	0.30	332.6	49.5	0.00347	198.9	6.9	6.5	26.6
354-27	OOM-1-24	0.10	19.8	0.13	14.2	21.5	0.00336	8.6	7.9	6.7	9.4
354-28	OOM-2-22	0.12	63.3	0.85	31.9	17.6	0.00127	24.7	11.7	37.0	15.8
354-29	OOM-2-23	0.10	54.7	0.12	30.2	31.2	0.00380	14.0	6.4	7.9	18.2
354-30, Rep 1	OOM-2-24	0.03	32.7	0.19	15.1	17.2	0.00050	11.1	10.2	4.5	25.1
354-30, Rep 2	OOM-2-24	0.03	34.3	0.09	15.4	16.7	0.00075	12.9	9.9	7.2	25.1
354-31	OOM-3-19	0.06	28.5	0.26	65.5	55.7	0.00222	57.5	17.4	8.7	69.5
354-32	OOM-3-20	0.05	25.7	0.12	20.5	25.1	0.00733	13.6	16.8	11.3	29.5
354-33	OOM-3-21	0.11	35.4	0.45	47.1	46.1	0.00204	40.5	19.7	40.0	52.0
354-34	OOM-3-22	0.01	30.0	0.25	8.2	16.7	0.00057	12.5	8.5	8.7	40.7
354-35	OOM-3-23	0.01	19.6	0.33	14.4	30.2	0.00109	11.3	30.7	4.7	51.5
354-36*	OOM-3-24	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

* Data not available at this time. It will be provided at a later date.

STANDARD REFERENCE MATERIAL

1643C	certified value	2.10 2.21 ±0.30	82.2 82.1 ±1.2	12.5 12.2 ±1.0	18.5 19.0 ±0.6	20.8 22.3 ±2.8	NA NA NA	60.2 60.6 ±7.3	32.7 35.3 ±0.9	12.9 12.7 ±0.7	76.5 73.9 ±0.9
1641b	certified value	NA NA NA	NA NA NA	NA NA NA	NA NA NA	NA NA NA	1.51 1.52 ±0.04	NA NA NA	NA NA NA	NA NA NA	NA NA NA

NA - Not applicable.

WES-OAKLAND COLUMN LEACHING (BRANNON)
METALS IN WATER SAMPLES (CF #354)

11/19/91

(Concentrations in ug/L)

MSL Code	Sponsor ID	Ag ICP/MS	As ICP/MS	Cd ICP/MS	Cr ICP/MS	Cu ICP/MS	Hg CVAA	Ni ICP/MS	Pb ICP/MS	Se ICP/MS	Zn ICP/MS
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MATRIX SPIKE RESULTS

Amount Spiked		1.00	20.0	1.00	20.0	20.0	25.0	20.0	5.0	20.0	20.0
354-8	OOM-1-19	0.00	22.2	0.29	27.5	40.1	0.00037	36.4	16.8	3.4	65.4
354-8+spike		0.41	44.7	1.18	38.5	51.2	0.02410	42.1	22.1	15.3	74.1
Amount Recovered		0.41	22.50	0.89	11.00	11.10	0.02373	5.70	5.30	11.90	8.70
Percent Recovery		41%	113%	89%	55%	56%	95%	29%	106%	60%	44%
Amount Spiked		1.00	20.0	1.00	20.0	20.0	25.0	20.0	5.0	NS	20.0
354-16	OOM-3-12	0.04	43.3	0.06	20.8	4.6	0.00113	7.9	1.3	NS	4.2
354-16+spike		0.70	59.9	1.11	34.7	22.1	0.02500	24.5	6.1	NS	25.8
Amount Recovered		0.66	16.60	1.05	13.90	17.50	0.02387	16.60	4.80	NS	21.60
Percent Recovery		66%	83%	105%	70%	88%	95%	83%	96%	NS	108%

NS - Not spiked.

Table D-1

Outer Oakland Metals
Column 3

Pore Volume Eluted	PARAMETER (ug/L)									
	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	
0.16	1.36	< 0.87	1.40	123	< 0.1	0.063	1255	1.68	176	
0.33	0.94	57.87	< 0.01	119	< 0.1	0.071	339	1.39	62.1	
0.51	0.39	5.99	< 0.01	75.6	< 0.1	0.065	179	1.31	60.4	
0.69	0.29	25.94	< 0.01	74.1	< 0.1	0.046	66.9	1.72	62.4	
0.87	0.75	17.46	< 0.01	53.7	< 0.1	0.033	22.0	1.38	38.4	
1.06	0.91	14.97	< 0.01	42.9	< 0.1	0.030	7.84	0.74	36.7	
1.23	0.78	24.94	< 0.01	43.2	< 0.1	0.046	< 1	0.51	36.3	
1.41	1.24	22.95	< 0.01	36.8	< 0.1	0.026	< 1	0.68	40.2	
1.80	0.32	29.43	0.03	79.6	0.63	0.015	29.2	0.38	26.4	
2.20	0.26	31.43	< 0.01	25.6	< 0.1	0.011	3.88	0.36	11.5	
2.54	0.02	33.5	0.03	14.6	2.3	0.001	4.2	0.9	3.8	
2.88	0.04	43.3	0.06	20.8	4.6	0.001	7.9	1.3	4.2	
3.26	0.05	35.5	0.11	19.3	4.1	0.001	8.2	2.9	9.1	
3.61	0.06	49.5	0.38	27.7	11.4	0.002	11.4	6.1	16.4	
3.98	0.06	47.2	0.80	31.8	15.4	0.030	22.7	7.8	24.6	
4.3	0.06	43.6	0.25	43.7	16.9	0.002	30.8	15.8	30.6	
4.64	0.06	39.9	0.55	62.0	43.5	0.003	48.8	26.9	59.2	
4.99	0.03	29.9	0.36	29.7	28.9	0.000	30.7	13.9	54.9	
5.3	0.06	28.5	0.26	65.5	55.7	0.002	57.5	17.4	69.5	
5.64	0.05	25.7	0.12	20.5	25.1	0.007	13.6	16.8	29.5	
6.02	0.11	35.4	0.45	47.1	46.1	0.002	40.5	19.7	52.0	
6.76	0.01	30.0	0.25	8.2	16.7	0.001	12.5	8.5	40.7	
7.42	0.01	19.6	0.33	14.4	30.2	0.001	11.3	30.7	51.5	

Table D-2

Outer Oakland Metals
Column 1

Pore Volume Eluted	PARAMETER (ug/L)									
	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	
0.13	0.90	69.84	0.47	591	< 0.1	0.007	1540	3.81	83.9	
0.36	0.98	62.61	0.15	155	< 0.1	0.067	1115	1.63	33.2	
0.54	0.06	43.40	< 0.01	49.1	6.21	0.073	286	0.78	14.9	
0.74	< 0.01	45.40	< 0.01	28.2	0.94	0.066	49.7	0.68	< 5	
0.96	0.03	47.89	0.15	36.5	2.74	0.043	24.4	0.43	53.8	
1.15	0.05	39.41	< 0.01	52.9	0.78	0.046	34.6	0.25	8.41	
1.37	< 0.01	43.40	< 0.01	16.5	1.47	0.041	8.41	0.26	5.74	
1.52	0.24	56.87	0.02	14.9	3.60	0.013	9.62	0.47	6.63	
1.72	0.03	49.39	0.07	13.5	2.63	0.044	14.9	0.34	10.7	
2.05	0.03	54.38	0.08	11.9	1.71	0.029	17.8	0.74	< 5	
2.42	0.05	51.38	0.01	14.0	4.38	0.021	29.0	1.74	< 5	
2.79	0.06	76.0	0.22	22.7	9.0	0.007	24.5	5.3	11.2	
3.17	0.06	60.0	0.70	29.6	18.1	0.002	21.9	10.6	20.7	
3.51	0.11	35.7	0.43	32.7	28.8	0.002	22.3	17.6	46.5	
3.85	0.06	29.8	0.59	32.9	39.2	0.017	24.6	16.0	35.3	
4.19	0.06	23.7	0.32	57.8	56.5	0.001	47.6	24.4	80.4	
4.57	0.11	26.3	0.38	30.8	37.4	0.005	28.3	17.6	49.5	
4.90	0.05	23.5	0.13	20.9	24.3	0.002	18.4	17.0	34.0	
5.25	0.00	22.2	0.29	27.5	40.1	0.000	36.4	16.8	65.4	
5.67	0.03	22.9	0.28	18.0	25.0	0.001	19.3	24.3	49.5	
6.00	0.08	21.4	0.17	23.2	31.4	0.003	24.7	16.6	35.5	
6.68	0.03	20.4	0.21	14.6	27.9	0.001	14.1	9.7	21.9	
7.37	0.06	22.8	0.30	332.6	49.5	0.003	198.9	6.9	26.6	
8.08	0.10	19.8	0.13	14.2	21.5	0.003	8.6	7.9	9.4	

Table D-3

Outer Oakland Metals
Column 2

Pore Volume Eluted	PARAMETER (ug/L)								
	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
0.17	0.29	34.92	1.17	1350	32.7	0.089	2200	13.6	1010
0.35	0.18	< 0.87	0.02	329	3.75	0.069	868	0.83	796
0.54	0.52	7.48	0.25	237	1.77	0.068	644	0.72	223
0.71	0.06	22.45	0.13	158	2.22	0.052	190	1.23	46.5
0.90	0.02	27.44	0.09	102	0.23	0.063	96.4	1.03	19.1
1.07	0.05	24.94	0.18	111	1.30	0.053	56.8	1.86	11.5
1.27	0.11	20.45	0.15	70.1	< 0.1	0.030	33.0	0.65	7.08
1.45	0.01	21.45	0.08	51.6	< 0.1	0.023	23.4	0.85	73.8
1.64	0.05	5.49	< 0.01	10.3	< 0.1	0.029	8.75	0.05	< 5
1.85	0.13	4.49	< 0.01	10.1	< 0.1	0.015	10.4	0.05	< 5
2.08	0.02	10.98	< 0.01	9.20	< 0.1	0.016	9.61	0.09	< 5
2.27	0.05	20.45	0.05	41.9	2.88	0.019	10.4	0.72	19.2
2.45	0.04	22.45	0.02	57.8	0.66	0.026	13.4	0.49	17.2
2.63	0.18	31.93	0.23	82.1	2.69	0.042	11.6	0.41	12.1
2.98	0.27	28.93	< 0.01	104	< 0.1	0.031	39.6	1.55	10.8
3.32	0.16	82.5	0.57	92.5	1.2	0.003	46.7	2.0	4.3
3.65	0.06	56.5	0.57	24.4	2.1	0.002	6.1	1.4	2.5
4.04	0.16	62.0	0.63	18.2	4.0	0.001	7.6	2.2	7.0
4.41	0.06	47.6	0.11	14.2	12.1	0.002	11.5	5.6	11.6
4.79	0.06	52.0	0.16	20.4	10.5	0.023	16.0	6.8	17.5
5.12	0.11	67.5	0.31	32.1	16.8	0.001	23.5	10.3	33.9
5.79	0.12	63.3	0.85	31.9	17.6	0.001	24.7	11.7	15.8
6.46	0.10	54.7	0.12	30.2	31.2	0.004	14.0	6.4	18.2
7.11	0.03	33.5	0.14	15.3	17.0	0.001	12.0	10.1	25.1

Table D-4

Outer Oakland Organics
Column 7

Parameter (ng/L)	PORE VOLUME ELUTED				
	0.71	2.32	3.71	5.32	9.35
Naphthalene	< 7.3	< 7.3	81.1	35.0	58.8
Acenaphthylene	< 9.2	< 9.2	< 9.2	< 9.2	9.5
Acenaphthene	< 5.9	< 5.9	< 5.9	< 5.9	< 5.9
Fluorene	< 6.9	< 6.9	< 6.9	17.9	25.3
Phenanthrene	< 7.8	< 7.8	< 7.8	48.0	85.4
Anthracene	< 11.5	< 11.5	< 11.5	36.3	54.4
Fluoranthene	< 5.9	< 5.9	42.5	79.7	150.5
Pyrene	< 6.5	< 6.5	164.8	401.5	622.2
Chrysene	< 19.2	< 19.2	< 19.2	58.3	90.4
Benzo(a)Anthracene	< 30.0	< 30.0	< 30.0	45.5	71.9
Benzo(b)Fluoranthene	< 14.7	< 14.7	72.1	178.3	196.5
Benzo(k)Fluoranthene	< 13.3	< 13.3	74.7	91.7	137.2
Benzo(a)Pyrene	< 6.4	< 6.4	< 6.4	122.8	169.5
Indeno(1,2,3-C,D)Pyrene	< 20.7	< 20.7	< 20.7	84.3	142.7
Dibenzo(A,H)Anthracene	< 21.6	< 21.6	< 21.6	21.6	< 21.6
Benzo(G,H,I)Perylene	< 20.0	< 20.0	< 20.0	91.5	137.4

Table D-5

Outer Oakland Organics
Column 8

Parameter (ng/L)	PORE VOLUME ELUTED				
	0.84	2.38	4.04	5.5	9.34
Naphthalene	< 7.3	< 7.4	< 39.3	< 7.3	86.4
Acenaphthylene	< 9.2	< 9.3	< 9.2	< 9.2	10.9
Acenaphthene	< 5.9	< 5.9	< 5.9	< 5.9	22.8
Fluorene	< 6.9	< 6.9	< 6.9	< 6.9	36.7
Phenanthrene	< 7.8	< 7.8	45.3	150.6	124.9
Anthracene	< 11.5	< 11.5	52.1	106.3	83.2
Fluoranthene	13.6	< 5.9	153.8	266.2	254.9
Pyrene	18.7	< 6.5	483.5	874.8	838.9
Chrysene	< 19.2	< 19.2	53.9	162.4	138.5
Benzo(a)Anthracene	< 30.0	< 30.0	80.2	149.6	114.8
Benzo(b)Fluoranthene	< 14.7	< 14.7	166.7	282.0	323.6
Benzo(k)Fluoranthene	< 13.3	< 13.3	130.7	308.4	230.4
Benzo(a)Pyrene	< 6.4	< 6.4	141.7	213.7	271.7
Indeno(1,2,3-C,D)Pyrene	< 20.7	< 20.7	72.5	122.1	207.0
Dibenzo(A,H)Anthracene	< 21.6	< 21.6	< 21.6	< 21.6	22.5
Benzo(G,H,I)Perylene	< 19.7	< 19.7	100.8	204.1	218.8

Table D-6

Inner Oakland Metals
Column 10

Pore volume Eluted	PARAMETER (ug/L)								
	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
0.28	0.24	10.30	0.92	186	55.8	0.217	950	4.18	248
0.59	0.37	16.57	0.02	262	1.96	0.016	1070	2.08	107
0.89	0.57	24.42	< 0.01	333	< 0.1	0.010	1400	1.53	65.4
1.70	0.68	30.46	< 0.01	286	< 0.1	0.008	1230	1.38	87.5
1.99	0.23	33.15	0.12	259	1.87	0.010	1190	1.59	35.9
2.27	0.35	28.67	0.11	262	< 0.1	0.015	1060	1.90	398
2.87	0.52	23.74	0.04	343	0.50	0.012	1010	1.86	16
3.55	0.05	21.05	0.06	319	0.37	0.007	932	0.22	25.6
4.22	0.06	17.02	0.05	46.2	2.39	0.002	519	1.30	15.3
4.89	0.05	8.29	< 0.01	38.2	5.64	0.002	288	2.47	9.00
5.53	0.04	13.44	< 0.01	19.8	7.88	0.004	252	4.42	14.8
6.23	0.05	11.20	0.17	9.69	16.5	0.002	31.4	10.8	28.8
6.84	0.11	13.44	0.15	31.1	30.9	0.016	39.9	14.1	45.7
7.48	0.17	11.20	0.25	55.0	53.5	0.013	59.4	26.9	81.3
8.30	0.18	8.51	0.32	68.9	57.7	0.009	77.6	23.4	91.4
9.07	0.02	10.30	0.15	11.7	16.5	0.001	24.5	23.8	68.2
9.70	0.06	12.09	0.34	43.2	36.8	0.006	54	39.8	124
10.56	0.22	6.27	0.39	95.8	93.5	0.007	123	40.3	150
11.31	0.29	6.72	0.49	113	97.0	0.013	133	44.1	159
11.95	0.04	8.51	0.19	15.0	36.3	0.005	22.2	23.2	55.0
12.61	0.04	8.06	0.08	6.91	22.7	0.008	8.53	11.4	14.5
13.69	0.46	10.30	1.42	44.6	44.6	0.017	46.2	16.8	30.7
14.90	0.06	10.75	0.12	7.09	20.2	0.003	9.44	9.56	23.5
15.95	0.09	8.96	0.21	27.8	52.8	0.004	35.9	13.4	48.3

Table D-7

Inner Oakland Metals
Column 11

Pore Volume Eluted	PARAMETER (ug/L)								
	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
0.35	0.80	5.38	0.78	146	25.3	0.021	735	3.60	248
0.65	0.30	14.33	0.17	225	< 0.1	0.011	731	1.56	84.3
1.19	0.22	16.57	0.30	230	< 0.1	0.001	804	1.22	121
1.55	0.25	20.61	< 0.01	250	< 0.1	0.001	800	1.12	90.5
1.84	0.05	14.33	0.07	334	13.2	0.006	792	1.38	63.8
2.14	0.25	11.20	0.10	271	16.5	0.012	775	4.84	69.5
2.67	0.06	7.62	0.03	301	0.78	0.007	823	0.33	55.7
3.34	0.12	5.38	0.09	343	2.86	0.009	924	0.27	53.0
3.86	0.17	5.38	0.28	378	2.83	0.010	973	0.69	48.8
4.59	0.06	9.41	0.10	309	2.36	0.006	767	0.61	47.0
5.09	0.27	11.65	0.30	489	8.57	0.006	956	0.43	38.9
5.92	0.06	10.30	0.08	445	3.15	0.008	847	0.22	52.4
6.52	0.04	11.65	0.17	289	2.65	0.007	667	0.96	45.9
7.04	0.06	10.30	0.09	117	4.82	0.007	450	0.44	12.1
7.67	0.11	10.75	0.18	76.8	3.35	0.008	530	0.46	10.9
8.24	0.05	13.44	0.15	26.7	5.89	0.013	441	0.79	10.5
8.78	0.04	13.44	0.17	15.5	14.5	0.012	389	2.05	17.7
9.48	0.06	15.23	0.08	8.81	16.2	0.007	206	2.74	17.1
10.07	0.64	14.33	0.48	50.2	52.2	0.074	187	10.7	33.2
10.69	0.07	6.27	0.13	12.6	38.1	0.007	116	11.3	36.4
11.43	0.05	2.24	0.12	15.9	46.7	0.006	95.9	20.2	50.6
12.46	1.43	12.47	< 0.01	55.8	51.9	0.021	85.9	19.3	85.6
13.65	0.19	12.47	0.20	27.8	59.9	0.007	59.6	15.5	87.1
14.81	0.05	15.96	0.06	9.33	38.7	0.003	33.1	16.3	80.9

Table D-8

Inner Oakland Metals
Column 12

Pore Volume Eluted	PARAMETER (ug/L)								
	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
0.28	3.65	< 2.06	1.00	364	17.6	0.368	5040	4.45	223
0.60	0.21	3.58	0.49	400	< 0.1	0.015	2660	1.66	142
0.90	0.22	6.27	0.58	561	< 0.1	0.013	2140	1.41	121
1.21	0.05	7.17	0.32	439	0.72	0.016	1530	0.36	112
1.61	0.06	6.72	0.27	647	0.46	0.007	1680	0.16	99.2
1.90	0.08	6.72	0.26	756	1.26	0.010	1580	0.23	96.9
2.69	0.03	5.99	0.27	569	1.33	0.016	1370	0.13	76.6
3.28	0.07	6.49	0.41	396	0.50	0.008	1270	0.41	70.3
3.85	0.06	7.98	0.24	330	0.61	0.007	1230	0.19	66.9
4.42	0.32	2.49	0.21	336	43.6	0.005	1270	2.02	77.7
5.00	0.07	4.99	0.22	532	2.17	0.006	1390	0.25	71.1
5.81	0.05	0.86	0.18	2.43	0.96	< 0.000	1300	0.19	22.0
6.35	0.04	0.86	0.11	68.1	0.67	< 0.000	1390	0.02	30.3
6.91	0.09	4.49	0.22	618	< 0.5	0.006	1470	0.18	77.5
7.59	0.04	< 0.86	0.12	3.14	< 0.5	0.001	1220	0.05	16.5
8.33	0.05	10.98	0.17	465	0.66	0.005	1390	0.24	41.6
8.90	0.05	7.98	0.22	417	5.65	0.004	1260	0.41	34.5
9.47	< 0.01	< 0.86	< 0.01	0.39	< 0.1	0.000	1230	0.05	9.07
10.15	0.16	3.99	< 0.01	422	< 0.1	0.008	1120	0.77	30.8
10.73	0.01	4.49	0.09	393	< 0.1	0.022	1130	0.22	33.9
11.40	0.06	3.99	0.07	434	0.23	0.066	923	0.31	22.0
12.51	0.03	6.49	0.23	255	0.69	0.068	625	0.78	14.9
13.54	1.43	5.49	< 0.01	171	< 0.1	0.050	487	1.17	< 5
14.54	0.26	5.99	0.04	124	1.53	0.034	447	0.96	12.4

Table D-9

Inner Oakland Organics
Column 17

Parameter (ng/L)	PORE VOLUME ELUTED				
	1.4	3.7	6.14	8.64	14.83
✓ Naphthalene	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3
✓ Acenaphthylene	< 9.2	< 9.2	< 9.2	< 9.2	< 9.2
Acenaphthene	< 5.9	< 5.9	< 5.9	102.8	< 5.9
✓ Fluorene	< 6.9	< 6.9	< 6.9	< 6.9	< 6.9
✓ Phenanthrene	< 7.8	< 7.8	< 7.8	< 7.8	< 7.8
✓ Anthracene	< 11.5	< 11.5	< 11.5	< 11.5	< 11.5
✓ Fluoranthene	< 5.9	19.7	19.7	21.8	29.4
✓ Pyrene	< 6.5	33.1	33.1	56.5	130.4
✓ Chrysene	< 19.2	< 19.2	< 19.2	< 19.2	< 19.2
✓ Benzo(a)Anthracene	< 30.0	< 30.0	< 30.0	< 30.0	< 30.0
Benzo(b)Fluoranthene	< 14.7	< 14.7	< 14.7	< 14.7	< 14.7
Benzo(k)Fluoranthene	< 13.3	< 13.3	< 13.3	< 13.3	< 13.3
✓ Benzo(a)Pyrene	< 6.4	< 6.4	< 6.4	< 6.4	< 6.4
✓ Indeno(1,2,3-C,D)Pyrene	< 20.7	< 20.7	< 20.7	< 20.7	< 20.7
Dibenzo(A,H)Anthracene	< 21.6	< 21.6	< 21.6	< 21.6	< 21.6
✓ Benzo(G,H,I)Perylene	< 20.0	< 20.0	< 20.0	< 20.0	< 20.0

Table D-10
Inner Oakland Organics
Column 18

Parameter (ng/L)	PORE VOLUME ELUTED				
	1.35	3.81	6.58	9.00	15.46
Naphthalene	< 7.3	< 7.3	< 7.3	< 7.3	J 3.5
Acenaphthylene	< 9.2	< 9.2	< 9.2	< 9.2	< 9.2
Acenaphthene	< 5.9	< 5.9	< 5.9	< 5.9	< 5.9
Fluorene	< 6.9	< 6.9	< 6.9	< 6.9	< 6.9
Phenanthrene	< 7.8	< 7.8	< 7.8	< 7.8	< 7.8
Anthracene	< 11.5	< 11.5	< 11.5	< 11.5	< 11.5
Fluoranthene	< 5.9	< 5.9	< 5.9	< 5.9	< 5.9
Pyrene	< 6.5	< 6.5	19.6	57.3	38.6
Chrysene	< 19.2	< 19.2	< 19.2	< 19.2	< 19.2
Benzo(a)Anthracene	< 30.0	< 30.0	< 30.0	< 30.0	< 30.0
Benzo(b)Fluoranthene	< 14.7	< 14.7	< 14.7	< 14.7	J 7.5
Benzo(k)Fluoranthene	< 13.3	< 13.3	< 13.3	< 13.3	J 4.2
Benzo(a)Pyrene	< 6.4	< 6.4	< 6.4	< 6.4	7.8
Indeno(1,2,3-C,D)Pyrene	< 20.7	< 20.7	< 20.7	< 20.7	< 20.7
Dibenzo(A,H)Anthracene	< 21.6	< 21.6	< 21.6	< 21.6	< 21.6
Benzo(G,H,I)Perylene	< 20.0	< 20.0	< 20.0	< 20.0	< 20.0

Table D-11

Total Organic Carbon Concentrations (mg/L)
In Column Leachates From Inner Oakland Sediment

Column 10		Column 11		Column 12	
<u>PV Eluted</u>	<u>TOC</u>	<u>PV Eluted</u>	<u>TOC</u>	<u>PV Eluted</u>	<u>TOC</u>
0.28	6.8	0.35	9.5	0.28	8.0
0.59	4.1	0.65	6.9	0.60	7.3
0.89	7.1	1.19	3.9	0.90	5.0
1.70	2.4	1.55	4.4	1.21	5.5
1.99	6.3	1.84	3.7	1.61	4.0
2.27	5.5	2.14	3.3	1.90	3.1
2.87	3.9	2.67	2.9	2.69	8.1
3.55	3.9	3.34	3.2	3.28	5.5
4.22	3.4	3.86	3.2	3.85	4.5
4.89	2.1	4.59	3.3	4.42	3.9
5.53	3.3	5.09	4.4	5.00	3.7
6.23	2.9	5.92	2.9	5.81	3.9
6.84	4.1	6.52	3.3	6.35	4.4
7.48	2.1	7.04	3.7	6.91	3.3
8.30	2.7	7.67	4.6	7.59	3.2
9.07	1.3	8.24	5.5	8.33	3.2
9.70	1.6	8.78	5.9	8.90	3.7
10.56	2.9	9.48	6.3	9.47	4.2
11.31	2.2	10.07	8.8	10.15	3.1
11.95	< 1.0	10.69	1.1	10.73	3.9
12.61	1.5	11.43	18.0	11.40	3.7
13.69	2.5	12.46	5.0	12.51	3.6
14.90	1.0	13.65	< 1.0	13.54	3.8
15.95	1.8	14.81	< 1.0	14.54	2.9
16.94	< 1.0	15.85	< 1.0	15.58	3.7
18.10	< 1.0			16.73	4.9
19.16	< 1.0			17.70	4.9
20.18	< 1.0				

Table D-12

Total Organic Carbon Concentrations (mg/L)
In Column Leachates From Outer Oakland Sediment

Column 1		Column 2		Column 3	
<u>PV Eluted</u>	<u>TOC</u>	<u>PV Eluted</u>	<u>TOC</u>	<u>PV Eluted</u>	<u>TOC</u>
0.13	148.5	0.17	431.9	0.16	444.1
0.36	77.0	0.35	279.1	0.33	284.1
0.54	36.4	0.54	246.7	0.51	195.6
0.74	17.7	0.71	135.8	0.69	145.7
0.96	11.8	0.90	104.5	0.87	103.6
1.15	10.7	1.07	87.4	1.06	65.1
1.37	10.1	1.27	63.4	1.23	51.3
1.52	11.0	1.45	40.8	1.41	43.9
1.72	13.7	1.64	10.9	1.80	29.2
2.05	18.5	1.85	8.9	2.20	17.9
2.42	23.5	2.08	9.1	2.54	3.0
2.79	15.7	2.27	24.3	2.88	4.1
3.17	18.8	2.45	34.3	3.26	3.7
3.51	4.0	2.63	44.8	3.61	5.7
3.85	3.1	2.98	30.4	3.98	4.7
4.19	< 1.0	3.32	6.8	4.30	6.2
4.57	< 1.0	3.65	6.1	4.64	3.9
4.90	< 1.0	4.04	4.4	4.99	< 1.0
5.25	< 1.0	4.41	7.5	5.30	< 1.0
5.67	< 1.0	4.79	9.5	5.64	< 1.0
6.00	2.3	5.12	22.3	6.02	< 1.0
6.68	8.7	5.79	17.6	6.76	< 1.0
7.37	1.6	6.46	8.3	7.42	4.3
8.08	4.2	7.11	9.8	8.06	2.9

APPENDIX E: PLANT TEST

ABBREVIATIONS USED IN TABLES E1-E12

PB = Plant Bioassay

WRS or WRS1 = WES Reference Soil

OHI1 or OAKINN = Oakland Inner

OHO1 or OAKOUT = Oakland Outer

WT or WT15 = Wetland (15-ppt salinity)

WTO - Wetland (0-ppt salinity)

AD = Air Dried

ADW = Air Dried and Washed

SA = *Spartina alterniflora*

SV = *Sporobolus virginicus*

CE = *Cyperus esculentus*

Table E1
Sediment pH, EC, % Moisture and % OM

	A	B	C	D	E	F	G	H	I
1	WES Laboratory Data For Oakland Harbor Sediments								
2	pH, Electrical Conductivity, Moisture and Organic Matter								
3									
4									
5	SEDIMENT	STATUS	REP	pH	EC	H2O	OM		
6					mmhos/cm	%	%		
7	OH11	WT	1	6.98	37	38.1	2.32		
8	OH11	AD	1	7.25	29.3	1.23	2.18		
9	OH11	ADW	1	6.83	3.2	1.27	1.71		
10	OH01	WT	1	7.3	35.3	61.34	3.9		
11	OH01	AD	1	7.32	38.3	1.73	3.58		
12	OH01	ADW	1	6.95	9.3	1.46	3.04		
13	WRS1	AD	1	6.41	0.56	0.97	3.95		
14									
15	OH11	WT	2	7.21	NA	40.58	2.3		
16	OH11	AD	2	7.21	NA	2.39	2.33		
17	OH11	ADW	2	6.67	NA	1.52	2.09		
18	OH01	WT	2	7.45	NA	60.68	4.94		
19	OH01	AD	2	7.58	NA	6.16	3.85		
20	OH01	ADW	2	7.21	NA	2.85	3.35		
21	WRS1	AD	2	6.47	NA	1.61	5.21		
22									
23	OH11	WT	3	7.15	NA	41.28	3.48		
24	OH11	AD	3	7.27	NA	2.61	2.27		
25	OH11	ADW	3	7.14	NA	1.42	2.15		
26	OH01	WT	3	7.54	NA	63.7	3.74		
27	OH01	AD	3	7.14	NA	5.71	3.68		
28	OH01	ADW	3	7.23	NA	2.79	3.59		
29	WRS1	AD	3	6.05	NA	2.48	3.87		
30									
31	OH11	WT	4	7.15	NA	41.28	2.53		
32	OH11	AD	4	7.26	NA	2.73	2.56		
33	OH11	ADW	4	7	NA	1.4	1.84		
34	OH01	WT	4	7.42	NA	59.87	4.11		
35	OH01	AD	4	7.42	NA	5.54	3.6		
36	OH01	ADW	4	7.13	NA	3.02	3.33		
37	WRS1	AD	4	6.43	NA	3.47	3.14		
38									
39									
40	OH11 = Oakland Harbor Inner Sediment								
41	OH01 = Oakland Harbor Outer Sediment								
42	WRS1 = WES Reference Soil								
43									
44	WT = Wet								
45	AD = Air Dry								
46	ADW = Air Dry and Washed								
47									
48	REP = Replicate								
49									
50	OM = Organic Matter								
51									
52									
53									
54									
55									
56									
57									
58									
59									
60									
61									
62									
63									

Table E2
Air Dry Sediment Heavy Metal Concentrations

(CF#209)

6/6/91

SEDIMENT DATA
Project: OAKLAND HARBOR
Sponsor: Richard Price

(Concentrations in mg/kg dry wt.)

SEDIMENT METAL DATA

Sample Code	Sponsor Code	Ag	As	Cd	Cr	Cu	Ni	Pb	Se	Zn
209-1	PB-OAKINN-AD-R1	0.089	6.30	0.13	287.0	24.5	64.5	11.8	0.19	59.7
209-2	PB-OAKINN-AD-R2	0.077	5.49	0.11	330.0	22.6	64.2	12.9	0.15	61.2
209-3	PB-OAKINN-AD-R3	0.074	4.47	0.11	348.0	24.3	67.3	14.9	0.15	60.4
209-4	PB-OAKINN-AD-R4	0.099	5.56	0.33	462.0	21.9	61.9	12.0	0.15	58.4
209-4	PB-OAKOUT-AD-R1 REP1	NA	8.6	NA	347.0	34.0	86.2	21.6	NA	90.3
209-4	PB-OAKOUT-AD-R1 REP2	NA	9.2	NA	392.0	33.8	85.6	20.4	NA	90.9
209-5	PB-OAKOUT-AD-R1 REP3	0.185	6.67	0.25	391.0	34.0	83.9	23.6	0.23	92.9
209-5	PB-OAKOUT-AD-R1 REP3	0.201	NA	0.24	NA	NA	NA	NA	0.23	NA
209-5	PB-OAKOUT-AD-R1 REP3	0.217	NA	0.25	NA	NA	NA	NA	0.27	NA
209-6	PB-OAKOUT-AD-R2	0.299	6.35	0.3	336.0	33.4	92.8	18.0	0.31	88.7
209-7	PB-OAKOUT-AD-R3	0.020	8.89	0.23	451.0	32.0	86.3	18.9	0.27	86.8
209-8	PB-OAKOUT-AD-R4	0.296	6.72	0.29	445.0	29.8	91.7	20.8	0.26	91.5
209-9	PB-AD-NBS-R1	0.087	11.0	0.3	88.0	22.2	34.6	28.3	0.69	129.9
209-10	PB-AD-NBS-R2	0.088	11.7	0.32	73.0	21.3	34.1	27.2	0.58	128.2
209-11	PB-AD-NBS-R3	0.079	10.6	0.3	72.0	20.2	32.2	28.1	0.58	126.0
209-12	PB-AD-NBS-R4	0.084	11.5	0.31	69.0	22.2	33.5	26.5	0.62	133.8
	PROCEDURAL BLANK	0.016	NA	< 0.015	NA	NA	NA	NA	< 0.12	NA
Standard Reference Material:										
MESS-1 (10/16)			11.9	0.59	76.0	26.6	30.6	32.9	0.35	179.4
MESS-1 (10/19)			10.9	0.61	82.0	26.5	30.8	34.2	0.38	170.2
MESS-1 (10/22)			10.3	NA	80.0	24.0	33.0	34.0	0.38	183.4
Certified	NA		(+/-1.2)	(+/- 0.1)	(+/- 11)	(+/- 3.8)	(+/- 2.7)	(+/- 6.1)	(+/- .06)	(+/- 17)

* Indicates analysis by AA.
NA Indicates data not available.

Table E3
Air Dry Washed Sediment Heavy Metal Concentrations
(Received October 1990)

MSL Code	Sponsor Code	$\mu\text{g/g}$									
		Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
238-1, Rep 1	PB-OAKINN-ADW-R1	0.10	3.84	0.11	451	22.4	0.071	61.3	14.0	<0.15	62.1
238-1, Rep 2	PB-OAKINN-ADW-R1	0.10	-	0.12	-	-	0.071	-	-	<0.15	-
238-2	PB-OAKINN-ADW-R2	0.10	4.49	0.10	329	21.4	0.065	61.1	12.1	<0.15	60.4
238-3	PB-OAKINN-ADW-R3	0.09	3.77	0.10	412	26.7	0.070	69.4	16.0	<0.15	64.8
238-4	PB-OAKOUT-ADW-R4	0.09	3.79	0.08	488	24.8	0.067	66.9	14.7	<0.15	62.7
238-5, Rep 1	PB-OAKOUT-ADW-R1	0.17	7.87	0.20	420	36.1	0.134	85.8	19.3	<0.15	91.9
238-5, Rep 2	PB-OAKOUT-ADW-R1	-	8.62	-	453	31.4	-	81.9	18.3	-	93.5
238-6	PB-OAKOUT-ADW-R2	0.17	7.11	0.23	427	29.4	0.170	83.1	18.3	<0.15	83.0
238-7	PB-OAKOUT-ADW-R3	0.18	8.02	0.20	372	33.0	0.157	87.2	18.3	<0.15	90.2
238-8	PB-OAKOUT-ADW-R4	0.17	6.87	0.20	496	32.0	0.154	86.5	20.0	<0.15	85.0
238-9	PB-ADW-NBS-R1	0.12	10.2	0.30	86	18.9	0.084	34.0	27.3	0.34	129.9
238-10	PB-ADW-NBS-R2	0.11	11.7	0.29	97	19.5	0.083	32.6	26.1	0.38	129.0
238-11	PB-ADW-NBS-R3	0.11	11.1	0.34	13	19.8	0.083	31.5	27.4	0.30	131.6
238-12	PB-ADW-NBS-RF	0.11	9.7	0.30	79	21.8	0.081	33.6	28.1	0.34	141.1

Standard Reference Material

Blank	0.01	-	<0.01	-	-	-	0.004	-	-	<0.15	-
MESS-1	0.11	10.0	0.55	79	27.3	0.180	0.180	32.2	32.2	0.30	180.8
Certified Values	NC	10.6	0.59	71	25.1	0.171	0.171	29.5	34.0	0.34	191.0
RPD	NC	± 1.2	± 0.10	± 11	± 3.8	± 0.014	± 0.014	± 2.7	± 6.1	± 0.06	± 17.0
	-	6%	7%	11%	9%	5%	5%	9%	5%	12%	5%

Table E3 (Concluded)
(Received October 1990)
(Continued)

	$\mu\text{g/g}$									
	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
PACS-1 Certified Values	1.68 NC NC -	- - - -	2.19 2.38 ±0.20 8%	- - - -	- - - -	4.72 4.57 ±0.16 3%	- - - -	- - - -	0.98 1.09 ±0.11 10%	- - - -
RPD										
1646-1 Certified Values	0.11 NC NC -	11.8 11.6 ±1.3 2%	0.31 0.36 ±0.07 14%	83 76 ±3 9%	21.5 18.0 ±3.0 19%	0.070 0.063 ±0.012 11%	32.1 32.0 ±3.0 <1%	27.9 28.2 ±1.8 1%	0.47 NC NC -	132.4 138.0 ±6.0 4%
RPD										

- = Data not available.
NC = Not certified.

Table E4

(CF#209)

12/12/90

(Concentrations in ug/kg Dry Wt.)

Sponsor Code :

		Concentrations in $\mu\text{g/g}$ wet wt.							
		OAKINN-R1	OAKINN-R1	OAKINN-R2	OAKINN-R3	OAKOUT-R1	OAKOUT-R2	OAKOUT-R3	OAKOUT-R4
209-1	REP1	209-1 REP2	209-1 REP3	209-2	209-3	209-5	209-6	209-7	209-8
214544	I	214544 II	21544 III	214548	214549	214551	214552	214553	214554

NAPHTHALENE	4	4	3	4	4	3	5	4
ACENAPHTHYLENE	2	2	2	2	2	2	3	3
ACENAPHTHENE	2	2	2	2	2	3	3	2
FLUORENE	2	2	2	2	2	4	5	3
PHENANTHRENE	14	15	15	18	16	21	22	20
ANTHRACENE	5	5	4	4	4	8	10	9
FLUORANTHENE	32	52	47	58	57	60	57	53
PYRENE	119	103	87	108	102	107	103	92
BENZ[<i>a</i>]ANTHRACENE	32	29	25	27	29	43	52	40
CHRYSENE	39	30	26	35	31	44	50	38
BENZOFLUORANTHENE**	102	92	87	103	116	106	109	115
BENZO[<i>a</i>]PYRENE	70	69	66	74	76	72	74	64
INDENO[1,2,3- <i>cd</i>]PYRENE	54	52	33	62	58	54	53	36
DIBENZ[<i>a,h</i>]ANTHRACENE	11	13	8	12	13	15	18	14
BENZO[<i>ghi</i>]PERYLENE	58	95	65	97	89	60	78	71
SURROGATE RECOVERY:								
D10-FLUORENE	110%	106%	98%	106%	104%	107%	104%	94%
D10-ANTHRACENE	78%	85%	79%	78%	78%	82%	81%	81%
D10-PYRENE	60%	66%	68%	59%	56%	53%	51%	57%

**** All benzofluoranthene isomers (b.i. and k) are quantified together.**

* Represents value calculated from a 1:10 dilution.

* Represents value calculated from a 1:10 dilution.

Table E4 (Concluded)

SEDIMENT DATA
Project: OAKLAND HARBOR
Sponsor: Richard Price

(CF#209)

12/12/90

SEDIMENT PAH DATA

STANDARD REFERENCE MATERIAL RESULTS

METHOD BLANK 10/18/90	TCT Code:	HS-5 SRLM 214579	CERTIFIED VALUES
NAPHTHALENE	< 1.9	123	250 (+/- 70)
ACENAPHTHYLENE	< 0.28	58	~150 (+/-)
ACENAPHTHENE	< 0.71	39	230 (+/- 100)
FLUORENE	< 0.56	18	400 (+/- 100)
PHENANTHRENE	< 0.76	3200**	5200 (+/- 1000)
ANTHRACENE	< 0.33	95	380 (+/- 150)
FLUORANTHENE	< 0.47	5800**	8400 (+/- 2600)
PYRENE	< 0.35	3100**	5800 (+/- 1800)
BENZ[AN]ANTHRACENE	< 0.33	1600**	2900 (+/- 1200)
CHRYSENE	< 0.28	1700**	2800 (+/- 900)
BENZO[FLUORANTHENE]**	< 0.35	3200**	~3000 (+/- 700)
BENZO[APYRENE	< 0.28	810**	1700 (+/- 800)
INDENO[1,2,3-cd]PYRENE	< 0.45	560**	1300 (+/- 700)
DIBENZ[ah]ANTHRACENE	< 0.26	240	200 (+/- 100)
BENZO[ghi]PERYLENE	< 0.22	670**	1300 (+/-)300
SURROGATE RECOVERY:			
D10-FLUORENE	98%	107%	
D10-ANTHRACENE	71%	73%	
D10-PYRENE	53%	71%	

< Indicates that parameter was not detected above the detection limit shown.

** All benzofluoranthene isomers (b,j, and k) are quantified together.

• Represents value calculated from a 1:10 dilution.

SIR/PAH Matrix Spike/Matrix Spike Duplicate Recovery
Client...BATTELLE NW

Lab Name: Twin City Testing

Invoice No.: 4410 90-7363

Matrix Spiked - Client Sample No.: MSL-209-1

COMPOUND	SPIKE ADDED (ng/gram)	SAMPLE CONC. (ng/gram)	MS CONC. (ng/gram)	MS % REC #	QC LIMITS REC.
Naphthalene	34	3.8	36	93	50-150
Fluorene	34	1.7	33	90	50-150
Anthracene	34	4.7	35	87	50-150
Fluoranthene	34	44	61	48 *	50-150
Benz[a]anthracene	34	29	54	74	50-150
Benzo[a]pyrene	34	68	88	59	50-150
Benzo[ghi]perylene	34	70	122	151 *	50-150

COMPOUND	SPIKE ADDED (ng/gram)	MSD CONC. (ng/gram)	MSD % REC #	% RPD #	QC LIMITS RPD REC.
Naphthalene	34	37	97	5	50 50-150
Fluorene	34	35	97	7	50 50-150
Anthracene	34	38	99	13	50 50-150
Fluoranthene	34	69	74	42	50 50-150
Benz[a]anthracene	34	60	90	20	50 50-150
Benzo[a]pyrene	34	91	67	13	50 50-150
Benzo[ghi]perylene	34	78	24 *	144 *	50 50-150

Column to be used to flag recovery and RPD values with an asterisk

* Values outside of QC limits

RPD: 1 out of 7 outside limits

Spike Recovery: 3 out of 14 outside limits

Analyst: David P. Johnson
Technical Review: Jeffrey E. Hillman

COMMENTS: _____

Table E5
Air Dry Washed Sediment PAH Concentrations

SEDIMENT DATA
Project: OAKLAND HARBOR
Sponsor: Richard Price

(CF#238) 2/7/91

SEDIMENT PAH DATA

(Concentrations in ug/kg Dry Weight)

Sponsor Code : OAKINN-R1
Battelle Code: 238-1

	OAKINN-R1 238-1	OAKINN-R2 238-2	OAKINN-R3 238-3	OAKINN-R4 238-4	OAKOUT-R1 238-5	OAKOUT-R2 238-6	OAKOUT-R3 238-7	OAKOUT-R4 238-8
NAPHTHALENE	13.1 U	14.2 U	11.5 U	10.9 U	16.5 U	11.7 U	11.3 U	11.7 U
ACENAPHTHYLENE	7.6 U	7.9 U	6.7 U	6.6 U	10.9 U	8.9 U	8.1 U	9.7 U
ACENAPHTHENE	5.0 U	5.4 U	4.4 U	4.1 U	6.3 U	4.4 U	4.3 U	4.4 U
FLUORENE	4.0 U	4.3 U	3.5 U	3.3 U	5.0 U	3.6 U	3.6 U	3.9 U
PHENANTHRENE	25.4 B	24.7 B	23.9 B	18.7 B	26.5 B	28.3 B	25.1 B	33.3 B
ANTHRACENE	7.1 B	6.2 B	6.9 B	5.6 B	7.1 B	10.6 B	10.3 B	13.2 B
FLUORANTHENE	69.6 B	79.4 B	68.1 B	61.4 B	82.3 B	73.1 B	64.2 B	75.5 B
PYRENE	106.0 B	131.5 B	105.7 B	96.8 B	130.6 B	116.6 B	105.0 B	120.9 B
BENZANTHRACENE	29.5 B	35.4 B	28.7 B	27.7 B	38.0 B	43.4 B	38.7 B	41.0 B
CHRYSENE	37.1 B	44.5 B	38.0 B	63.2 B	48.6 B	50.7 B	47.1 B	52.0 B
BENZO [B] FLUORANTHENE *	120.8	134.5	104.7	97.3	136.2	110.5	101.6	103.1
BENZO [A] PYRENE	67.2	75.9	65.1	58.4	76.6	66.7	60.9	65.1
INDENO [1,2,3-cd] PYRENE	63.2	73.2	61.3	53.3	73.9	58.2	55.2	67.3
DIBENZO [a,h] ANTHRACENE	10.9	13.7	11.1	10.0	13.8	13.3	12.1	16.0
BENZO [g,h] PERYLENE	85.5	96.6	79.6	71.0	96.7	73.0	69.6	83.1
SURROGATE RECOVERY:								
D10-FLUORENE	127%	116%	118%	109%	152%	112%	109%	124%
D10-ANTHRACENE	120%	109%	101%	103%	132%	108%	109%	133%
D10-PYRENE	118%	131%	112%	111%	151%	115%	106%	123%

U Indicates analyte not detected at or above detection limit shown
* All benzofluoranthene isomers are quantified together
B Indicates analyte detected in method blank. (not blank corrected)

Table E5 (Concluded)

SEDIMENT DATA
Project: OAKLAND HARBOR
Sponsor: Richard Price

(CF#238)

2/7/91

SEDIMENT PAH QUALITY CONTROL DATA

(Concentrations in ug/kg Dry Weight)

METHOD BLANK

NAPHTHALENE
ACENAPHTHYLENE
ACENAPHTHENE
FLUORENE
PHENANTHRENE
ANTHRACENE
FLUORANTHENE
PYRENE
BENZANTHRACENE
CHRYSENE
BENZO (B) FLUORANTHENE *
BENZO (K) PYRENE
INDENOT (1,2,3-cd) PYRENE
DIBENZO (a,h) ANTHRACENE
BENZO (g,h) PERYLENE
SURROGATE RECOVERY:
D10-FLUORENE
D10-ANTHRACENE
D10-PYRENE

1.07 U
0.16 U
0.41 U
0.32 U
0.58
0.19 U
0.38
0.43
0.35
0.17
0.2 U
0.16 U
0.28 U
0.15 U
0.13

Sample Spiked: 238-4 (OAKINN-R4)

MATRIX SPIKE

Amount Spiked	Amount Recovered	Percent Recovered
24	36	120%
NS		
NS		
24	39	154% **
NS		
24	41	143%
24	124	173% **
NS		
24	76	160% **
NS		
NS		
24	110	137%
NS		
NS		
24	138	173% **

138%
126%
147%

NS Indicates analyte not spiked

U Indicates analyte not detected at or above detection limit shown

** Indicates outside of control limits (control limits: 50 - 150 %)

Table E6
Air Dry Sediment Butyltin Concentrations

SEDIMENT DATA
Project: OAKLAND HARBOR
Sponsor: Richard Price

(CF#209)

12/12/90

SEDIMENT BUTYLtin RESULTS

(Concentrations in ug/kg Dry Wt.)

Sample Code	Sponsor Code	TETRA-BUTYLtin	TRI-BUTYLtin	DI-BUTYLtin	MONO-BUTYLtin	% Surrogate Recovery PROPYLtin
209-1	PB-OAKINN-AD-R1	1.3U	3	2.1	1.1U	35%
209-1 rep	PB-OAKINN-AD-R1 rep	1.3U	3	2.1	1.2U	42%
209-2	PB-OAKINN-AD-R2	1U	2.4	2.4	0.9U	33%
209-3	PB-OAKINN-AD-R3	1.1U	1.9	2	1U	47%
209-4	PB-OAKINN-AD-R4	1.2U	1.6	2	1.1U	54%
209-5	PB-OAKOUT-AD-R1	1.2U	2.6	37.3	1.1U	47%
209-6	PB-OAKOUT-AD-R2	1.1U	2.1	7.2	1U	45%
209-7	PB-OAKOUT-AD-R3	1.2U	2.2	36.7	2.1	47%
209-8	PB-OAKOUT-AD-R4	1.3U	2.3	22.5	1.2U	55%
	method blank	1.4U	1.6U	1.3U	1.3U	40%

U indicates analyte was not detected at detection limit shown.

MATRIX SPIKE RECOVERIES:

209-21 SPIKE	NS	71.2	71.7	19.3	42%
Percent Recovery:		59%	60%	16%	
NS Indicates not spiked					

Table E7
Air Dry Washed Sediment Butyltin Concentrations

SEDIMENT DATA
Project: OAKLAND HARBOR
Sponsor: Richard Price

(CF#238)

8/24/91

SEDIMENT BUTYLtin RESULTS

Sample Code	Sponsor Code	(Concentrations in ug/kg Dry Weight)					% Surrogate Recovery
		TETRA-BUTYLtin	TRI-BUTYLtin	DI-BUTYLtin	MONO-BUTYLtin	PROPYLTin	
238-1	PB-OAKINN-ADW-R1	0.8 U	1.9	1.8	1.0		48%
238-2	PB-OAKINN-ADW-R2	0.8 U	2.9	1.2	1.0		43%
238-3	PB-OAKINN-ADW-R3	0.7 U	1.9	1.1	0.9		38%
238-4	PB-OAKINN-ADW-R4	0.8 U	2.3	1.2	1.3		41%
238-5	PB-OAKOUT-ADW-R1	0.8 U	1.6	1.3	1.2		57%
238-6	PB-OAKOUT-ADW-R2	0.7 U	1.5	1.0	0.8		58%
238-7	PB-OAKOUT-ADW-R3	0.8 U	1.6	0.7 U	0.8		48%
238-8	PB-OAKOUT-ADW-R4						
	METHOD BLANK	0.7 U	1.2	0.6 U	0.6 U		57%

STANDARD REFERENCE MATERIAL:

PACS-1

CERTIFIED VALUES:

NC 8 U 1270 (±220) 651 528 218 80%

Butyltin Re-analyses (3/1/91)

238-7R 0.7 U 0.8 U 1.3 1.1 70%
238-8R 3.1 1.0 U 0.9 6.4 83%
Blank 0.7 U 1.3 0.7 U 24.3 75%

U Indicates analyte not detected at detection limit shown
NC Indicates not certified

** SAMPLE EXTRACT LOST DURING PROCESSING; CURRENTLY BEING RE-ANALYZED

Table E8
Total Fresh and Dry Weight Plant Yields

OBS	SEDIMENT	STATUS	PLANT	REP	FRESH	OVEN-DRY
1	WRS1	WT15	SA	1	44.959	26.5264
2	WRS1	WT15	SA	2	53.758	29.0179
3	WRS1	WT15	SA	3	37.376	19.4634
4	WRS1	WT15	SA	4	41.561	20.9487
5	WRS1	WT0	SA	1	124.870	50.6000
6	WRS1	WT0	SA	2	74.970	32.8400
7	WRS1	WT0	SA	3	128.180	55.7855
8	WRS1	WT0	SA	4	85.419	38.8812
9	WRS1	AD	SA	1	44.531	16.3819
10	WRS1	AD	SA	2	37.588	17.2215
11	WRS1	AD	SA	3	40.560	12.1695
12	WRS1	AD	SA	4	39.102	8.1902
13	WRS1	AD	SV	1	40.679	18.6443
14	WRS1	AD	SV	2	44.152	19.5275
15	WRS1	AD	SV	3	33.303	21.7392
16	WRS1	AD	SV	4	20.454	20.6116
17	WRS1	AD	CE	1	93.840	18.5709
18	WRS1	AD	CE	2	79.030	15.6400
19	WRS1	AD	CE	4	69.520	13.7580
20	OHI1	WT	SA	1	6.225	3.6958
21	OHI1	WT	SA	3	0.926	0.5498
22	OHI1	WT	SA	4	5.363	3.1840
23	OHI1	AD	SV	1	0.000	0.0000
24	OHI1	AD	SV	2	0.000	0.0000
25	OHI1	AD	SV	3	0.000	0.0000
26	OHI1	AD	SV	4	0.000	0.0000
27	OHI1	ADW	SV	1	7.018	5.7141
28	OHI1	ADW	SV	2	7.214	5.8736
29	OHI1	ADW	SV	3	6.360	5.1783
30	OHI1	ADW	SV	4	2.267	1.8458
31	OHI1	ADW	CE	1	11.444	4.3418
32	OHI1	ADW	CE	2	9.021	3.4226
33	OHI1	ADW	CE	3	7.646	2.9009
34	OHI1	ADW	CE	4	8.210	3.1149
35	OHO1	WT	SA	1	0.341	0.1812
36	OHO1	WT	SA	2	5.850	3.1081
37	OHO1	WT	SA	4	6.070	3.2250
38	OHO1	AD	SV	1	0.000	0.0000
39	OHO1	AD	SV	2	0.000	0.0000
40	OHO1	AD	SV	3	0.000	0.0000
41	OHO1	AD	SV	4	0.000	0.0000
42	OHO1	ADW	SV	1	11.361	9.4024
43	OHO1	ADW	SV	2	10.500	8.6898
44	OHO1	ADW	SV	3	8.516	7.0478
45	OHO1	ADW	SV	4	12.555	10.3905
46	OHO1	ADW	CE	1	9.330	2.5573
47	OHO1	ADW	CE	2	16.769	4.5964
48	OHO1	ADW	CE	4	11.299	3.0970

Table E9
Heavy Metal Plant Tissue Concentrations

1	A	B	C	D	E	F	G	H	I	J	K	L	M
2	SED	WT	PLANT	REP	ug/g As	ug/g Cd	ug/g Cr	ug/g Cu	ug/g Pb	ug/g Ni	ug/g Se	ug/g Ag	ug/g Zn
3	WRS1	WT	SA	1	<1	0	<1	3.8	3.6	1.2	0	<0.2	14.6
4	WRS1	WT	SA	2	<0.998	0.06	<0.998	2.794	4.391	1.198	0	<0.2	8.583
5	WRS1	WT	SA	3	<0.996	0.08	<0.996	2.988	3.785	1.594	0	<0.2	10.558
6	WRS1	WT	SA	4	<0.994	0	<0.994	3.579	4.573	1.392	25.05	<0.2	10.537
7	WRS1	AD	SV	1	<0.996	0.159	<0.996	2.59	0	1.394	0	<0.2	2.789
8	WRS1	AD	SV	2	<0.994	0.139	<0.994	2.386	0	1.59	0	<0.2	1.193
9	WRS1	AD	SV	3	<0.994	0.08	<0.994	2.187	0	0.994	0	<0.2	5.964
10	WRS1	AD	CE	1234	<0.994	1.789	<0.994	8.748	0.199	1.59	0	<0.2	68.588
11	WRS1	AD	CE	1234	<0.992	1.845	<0.992	8.532	0	1.786	0	<0.2	77.183
12	WRS1	AD	CE	1234	<0.994	1.511	<0.994	8.151	0.199	1.988	0	<0.2	75.746
13	NBS	1572		1	3.579	0	0.557	14.314	13.718	<0.994	0	<0.2	27.634
14	CERTIFIED VALUE				3.1	0.03	0.8	16.5	13.3	0.6	0.025	NA	29
15	% Recovery				115	ND	69.6	86.8	103	ND	ND		95.3
16	BLANK												
17	BLANK			1	<0.005	0.0003	0.005	<0.005	0.003	<0.005	0.005	<0.0010	0.041
18	WRS1	AD	SV	4	<0.984	0.197	<0.984	2.165	7.283	<0.984	<0.984	<0.2	0
19	OH11	WT	SA	134	<0.994	0.06	0.994	2.187	3.976	1.193	<0.994	<0.2	2.783
20	OH11	ADW	SV	1234	<0.99	0.238	<0.99	7.327	0.198	<0.99	<0.99	<0.2	22.772
21	OH11	ADW	SV	1234	<0.982	0.275	<0.982	7.269	0.393	0.982	<0.982	<0.2	16.11
22	OH11	ADW	SV	1234	<1	0.24	<1	6.4	0	1	<1	<0.2	12.8
23	OH11	ADW	CE	1234	<1	1	<1	8	0.2	2.4	<1	<0.2	62.2
24	OH01	WT	SA	124	<0.99	0.02	<0.99	<0.99	4.554	<0.99	<0.99	<0.2	3.366
25	OH01	ADW	SV	12	<0.996	0.558	<0.996	9.562	3.386	1.992	<0.996	1.992	38.048
26	OH01	ADW	SV	34	<0.994	0.795	<0.994	9.543	3.38	1.392	<0.994	<0.2	45.527
27	OH01	ADW	CE	124	<0.994	2.187	<0.994	10.338	3.976	1.193	14.712	3.419	100.398
28	NBS	1572			3.968	0	0.734	14.286	14.484	1.587	<0.992	<0.2	23.214
29	CERTIFIED VALUE				3.1	0.03	0.8	16.5	13.3	0.6	0.025(ND)	NA	29
30	% RECOVERY				128	ND	91.8	86.6	109	265	ND		80
31	BLANK				<0.005	<0.0001	<0.005	<0.005	0.003	<0.005	<0.005	<0.0010	0.047
32	BLANK												
33	Blanks above detection limits were subtracted from sample concentrations.												
34	Concentrations of 0 were less than blank concentrations.												
35	NBS 1572 Concentrations for Cd, Ni, and Se were near or below detection limits; % recovery was not determined.												
36	NA=Not available												
37	ND = Not determined												

Table E10
Mercury Plant Tissue Concentrations

JOB FILE: 13141

DATE: 29 JUL 91

***** ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 1 OF 3) *****

JOB DESCRIPTION: OAKLAND INN/OUT - R. PRICE
CHEM. PRESERVATIVE:

JOB NUMBER: CQED38301E000F
TYPE OF SAMPLE: PLANT TISSUE

RECEIPT DATE: 28 JUN 91
EST. COMP. DATE: 05 AUG 91

COLUMN..... 1
ANALYTE..... 8
MG/KG..... NG

SAMP #	DESCRIPTION				ROW
13141	WRS-WT15-SA-1	CONC	<0.032		1
		XREC	128.0		
		DUPL	<0.032		
		OID	56651205		
13142	WRS-WT15-SA-2	CONC	0.032		2
		XREC			
		DUPL	<0.032		
		OID	56651205		
13143	WRS-WT15-SA-3	CONC	<0.032		3
		XREC			
		DUPL	<0.032		
		OID	56651205		
13144	WRS-WT15-SA-4	CONC	<0.032		4
		XREC			
		DUPL			
		OID	56651205		
13145	WRS-AD-SV-1	CONC	0.032		5
		XREC			
		DUPL	0.032		
		OID	56651205		
13146	WRS-AD-SV-2	CONC	<0.032		6
		XREC			
		DUPL	<0.032		
		OID	56651205		

HG Mercury

OB FILE: 13141

DATE: 29 JUL 91

***** ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 2 OF 3) *****

JOB DESCRIPTION: OAKLAND INN/OUT - R. PRICE
 MEM. PRESERVATIVE:

JOB NUMBER: CQED38301E000F
 TYPE OF SAMPLE: PLANT TISSUE

RECEIPT DATE: 28 JUN 91
 EST. COMP. DATE: 05 AUG 91

COLUMN..... 1
 ANALYTE..... 8
 MG/KG..... HG

JAMP #	DESCRIPTION	CONC	%REC	DUPL	OID	ROW
13147	WRS-AD-SV-3	0.032		0.032	56651205	7
3148	WRS-AD-CE-1234	0.032		0.032	56651205	8
13149	WRS-AD-SV-4	<0.027	72.0	<0.027	56651205	9
13150	^{WT} OAKINN-WK-SA-134	<0.032		0.032	56651205	10
13151	OAKINN-ADW-SV-1234	<0.032		<0.032	56651205	11
13152	OAKINN-ADW-CE-1234	<0.032	64.0	<0.032	56651205	12

G Mercury

DATE: 29 JUL 91

JOB FILE: 13141

***** ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 3 OF 3) *****

JOB DESCRIPTION: OAKLAND INN/OUT - R. PRICE
CHEM. PRESERVATIVE:JOB NUMBER: CQED38301E000F
TYPE OF SAMPLE: PLANT TISSUERECEIPT DATE: 28 JUN 91
EST. COMP. DATE: 05 AUG 91COLUMN..... 1
ANALYTE..... 8
MG/KG..... HG

SAMP #	DESCRIPTION			ROW
13153	OAKOUT-WY-SA-124	CONC 0.045 XREC DUPL OID 56651205	 	13
13154	OAKOUT-ADW-SV-12	CONC <0.032 XREC DUPL 0.032 OID 56651205	 	14
13155	OAKOUT-ADW-SV-34	CONC <0.032 XREC DUPL 0.043 OID 56651205	 	15
13156	OAKOUT-ADW-CE-124	CONC <0.032 XREC DUPL 0.032 OID 56651205	 	16
HG	Mercury			

Table E11
PAH Plant Tissue Concentrations

PAH CONCENTRATIONS IN PLANT

TISSUE
(ci# 344)
10/24/91

Sponsor Code:	method blank	OAKINN	OAKINN	OAKINN	OAKOUT	OAKOUT	OAKOUT
Sample Number	JM11PB	WT-SA-134	ADW-SV-1234	ADW-CE-1234	WT-SA-124	ADW-SV-12	ADW-SV-34
Species	NA	344-01	344-02	344-03	344-04	344-05	344-06
Wet Weight(g)	10.000	PLANT	PLANT	PLANT	PLANT	PLANT	PLANT
		3.907	6.454	10.291	3.763	5.905	5.286

PAHs

(Concentrations in ug/kg wet wt.)

naphthalene	35.825	26.8 B	6.34 UB	3.98 UB	51.08 B	6.93 UB	10.57 B
acenaphthylene	0.987 J	4.58 J	4.33 J	3.9 U	8.17 J	6.8 U	7.59 U
acenaphthene	1.334 J	2.82 J	2.43 J	1.35 J	6.56	3.53 J	3.43 J
fluorene	1.051 J	4.67 J	2.18 J	1.06 J	3.69 J	1.97 J	2.65 J
phenanthrene	4.434	18	10.59	5.26	21.39	10.28	14.26
anthracene	0.922 J	3.12 J	1.09 J	1.19 J	3.68 J	1.44 J	1.98 J
fluoranthene	0.645 J	5.1	2.92	1.11 J	5.51	3.33	4.05
pyrene	1.031 J	6.57	2.59 J	1.43 J	6.22	2.74 J	3.04 J
benz[a]anthracene	0.625 J	1.49 J	0.77 J	0.62 J	1.67 J	5.03 U	0.82 J
chrysene	0.676 J	1.76 J	1.28 J	0.8 J	1.94 J	1.59 J	1.6 J
benzo[b]fluoranthene	0.732 J	7.75 U	4.69 U	2.94 U	8.05 U	5.13 U	5.73 U
benzo[k]fluoranthene	0.450 J	6.49 U	3.93 U	2.47 U	6.74 U	4.3 U	4.8 U
benzo[a]pyrene	2.642 U	6.76 U	4.09 U	2.57 U	7.02 U	4.47 U	5 U
Indeno[1,2,3-c,d]pyrene	3.167 U	8.11 U	4.91 U	3.08 U	8.42 U	5.36 U	5.99 U
dibenz[a,h]anthracene	2.154 U	5.51 U	3.34 U	2.09 U	5.72 U	3.65 U	4.08 U
benzo[g,h,i]perylene	4.295 U	10.99 U	6.66 U	1.18 J	11.41 U	7.27 U	8.13 U

Surrogate Percent Recoveries

naphthalene-d8 (% Rec)	75.54	49.39	49.17	59.37	23.94 &	46.16	46.06
acenaphthene-d10 (% Rec)	85.43 M	70.78 M	78.65 M	81.98 M	47.52 M	83.5 M	88.75 M
benzo[a]pyrene-d12 (% Rec)	70.41	64.24	69.11	81.78	50.46	70.61	84.9

B Indicates sample has been corrected for blank concentration

J - Value below MDL

U - Not Detected reported as MDL in ug/kg

M - Matrix Interference

& - Surrogate Recovery out of QC range (40 - 120%)

Table E11 (Continued)

PAH CONCENTRATIONS IN PLANT

TISSUE

(c/# 344)

10/24/91

Sponsor Code:	OAKOUT	WRS	WRS	WRS	WRS	WRS
Sample Number	ADW-CE-124	WR15-SA-1	WR15-SA-2	WR15-SA-3	WR15-SA-4	AD-SV-2
Species	344-07	344-08	344-09	344-10	344-11	344-13
Wet Weight(g)	PLANT	PLANT	PLANT	PLANT	PLANT	PLANT
	14.710	14.485	18.734	15.506	15.736	12.392

PAHs

(Concentrations in ug/kg wet wt.)

naphthalene	2.78 UB	2.83 UB	2.18 UB	4.28 B	2.6 UB	0.49 JB	3.3 UB
acenaphthylene	1.83 J	1.16 J	0.55 J	2.59 U	2.15 J	3.75	2.3 J
acenaphthene	1.02 J	1.5 U	1.16 U	1.4 U	1.21 J	1.72 U	1.75 U
fluorene	1.06 J	0.97 J	0.74 J	1.45 J	1.05 J	1.15 J	1.09 J
phenanthrene	5.24	7.12	4.69	6.75	6.21	6.28	6.01
anthracene	0.73 J	0.94 J	0.59 J	0.78 J	0.66 J	0.75 J	0.74 J
fluoranthene	1.19	3.75	2.34	2.8	2.93	3.04	3.08
pyrene	1.42 J	3.72	2.07	2.77	2.88	2.45	2.62
benz[a]anthracene	0.36 J	0.5 J	0.28 J	0.46 J	0.33 J	0.26 J	0.26 J
chrysene	0.42 J	0.69 J	0.31 J	0.6 J	0.46 J	1 J	0.98 J
benzo[b]fluoranthene	0.57 J	2.09 U	0.29 J	1.95 U	1.93 U	2.41 U	1.31 J
benzo[k]fluoranthene	1.73 U	1.75 U	1.35 U	1.64 U	1.61 U	2.02 U	2.05 U
benzo[a]pyrene	1.8 U	1.82 U	1.41 U	1.7 U	1.68 U	2.1 U	2.13 U
Indeno[1,2,3-c,d]pyrene	2.15 U	2.19 U	1.69 U	2.04 U	2.01 U	2.52 U	2.56 U
dibenz[a,h]anthracene	1.46 U	1.49 U	1.15 U	1.39 U	1.37 U	1.71 U	1.74 U
benzo[g,h,i]perylene	2.92 U	2.97 U	2.29 U	2.77 U	2.73 U	5.41	3.47 U

Surrogate Percent Recoveries

naphthalene-d8 (% Rec)	42.43	56.06	64.26	60.06	57.15	60.37	56.09
acenaphthene-d10 (% Rec)	77 M	71.74 M	85.73 M	80.82 M	89.32 M	103.69 M	90.69 M
benzo[a]pyrene-d12 (% Rec)	72.89	39.37 &	84.81	75.79	80.27	81.4	73.29

B Indicates sample has been corrected for blank concentration

J - Value below MDL

U - Not Detected reported as MDL in ug/kg

M - Matrix Interference

& - Surrogate Recovery out of QC range (40 - 120%)

Table E11 (Concluded)

PAH CONCENTRATIONS IN PLANT

TISSUE

(cf# 344)

10/24/91

Sponsor Code:	WRS	WRS	WRS
Sample Number	AD-SV-3	AD-SV-4	AD-CE-1234
Species	344-14	344-15	344-16
Wet Weight(g)	PLANT	PLANT	PLANT
	11.815	11.654	15.026

PAHs

(Concentrations in ug/kg wet wt.)

naphthalene	3.46 UB	43.1 B	2.72 UB
acenaphthylene	1.8 J	1.37 J	1.75 J
acenaphthene	1.16 J	1.36 J	1.44 U
fluorene	0.9 J	1.92 J	0.78 J
phenanthrene	5.31	6.7	4.25
anthracene	0.64 J	0.9 J	0.67 J
fluoranthene	2.49	2.38	0.76 J
pyrene	1.83	1.82	0.84 J
benz[a]anthracene	0.3 J	0.26 J	0.17 J
chrysene	0.89 J	0.87 J	0.24 J
benzo[b]fluoranthene	2.56 U	0.87 J	2.02 U
benzo[k]fluoranthene	2.15 U	2.18 U	1.69 U
benzo[a]pyrene	2.24 U	2.27 U	1.76 U
indeno[1,2,3-c,d]pyrene	2.68 U	2.72 U	2.11 U
dibenz[a,h]anthracene	1.82 U	1.85 U	1.43 U
benzo[g,h,i]perylene	3.64 U	3.69 U	1.61 J

Surrogate Percent Recoveries

naphthalene-d8 (% Rec)	61.62	61.81	55.7
acenaphthene-d10 (% Rec)	102.93 M	101.21 M	92.13 M
benzo[a]pyrene-d12 (% Rec)	77.8	80.23	87.5

E Indicates sample has been corrected for blank c

J - Value below MDL

U - Not Detected reported as MDL in ug/kg

M - Matrix Interference

& - Surrogate Recovery out of QC range (40 - 120%)

Table E12
Organotin Plant Tissue Concentrations

BUTYLtin CONCENTRATIONS IN PLANTS
(cf# 344)

(Concentrations in ug/kg wet wt.)

Sponsor Code:	OAKINN	OAKINN	OAKINN	OAKOUT	OAKOUT	OAKOUT
Sample ID	WT-SA-134	ADW-SV-1234	ADW-CE-1234	WT-SA-124	ADW-SV-12	ADW-SV-34
Wet Weight (g)	344-1	344-2	344-3	344-4	344-5	344-6
Percent Dry Weight	1.0	1.5	2.1	1.0	1.0	1.1
Dry Weight (g)	41.7	76.5	20.7	NA	74.7	77.3
	0.43	1.16	0.43	NA	0.75	0.82
TBT	28.7 J	8.5 J	100.9	38.3 U	38.3 U	38.3 U
DBT	18.1 U	18.1 U	18.1 U	18.1 U	18.1 U	18.1 U
MBT	16.4 U	16.4 U	16.4 U	16.4 U	16.4 U	16.4 U
Surrogate:	48.3	57.8	50.9	62.7	47.7	23.9
TPT %Recovery						

(Concentrations in ug/kg wet wt.)

Sponsor Code:	OAKOUT	WRS	WRS	WRS	WRS	WRS
Sample ID	ADW-CE-124	WR15-SA-1	WR15-SA-2	WR15-SA-3	WR15-SA-4	AD-SV-1
Wet Weight (g)	344-7	344-8	344-9	344-10	344-11	344-12
Percent Dry Weight	2.0	1.5	2.0	1.7	2.0	2.0
Dry Weight (g)	19.3	41.9	40.6	37.4	42.0	75.4
	0.39	0.63	0.82	0.65	0.86	1.52
TBT	38.3 U	21.0 J	38.3 U	38.3 U	38.3 U	38.3 U
DBT	18.1 U	18.1 U	18.1 U	18.1 U	18.1 U	18.1 U
MBT	16.4 U	16.4 U	16.4 U	16.4 U	16.4 U	16.4 U
Surrogate:	20.0	39.3	22.5	56.0	46.6	27.1
TPT %Recovery						44.5
						AD-SV-2
						344-13
						2.0
						69.8
						1.42
						11.2 J
						18.1 U
						10.7 J

U - Not detected, reported as MDL
J - Value below MDL

Table E12 (Concluded)

BUTYLtin CONCENTRATIONS IN PLANTS

(cf# 344)

(Concentrations in ug/kg wet wt.)

Sponsor Code: Sample ID	WRS		WRS		METHOD BLANK	MATRIX SPIKE JL74MS	MATRIX SPIKE %
	AD-SV-3 344-14	AD-SV-4 344-15	AD-CE-1234 344-16	JL76PB			
Wet Weight (g)	2.0	2.0	2.0	2.0	2.0	2.4	RECOVERY
Percent Dry Weight	75.5	70.6	15.8	NA	NA	40.6	
Dry Weight (g)	1.51	1.44	0.32	NA	NA	0.95	
TBT	38.3 U	38.3 U	38.3 U	38.3 U	38.3 U	237.3	169.4 &
DBT	18.1 U	18.1 U	18.1 U	18.1 U	18.1 U	216.4	187.9
MBT	4.9 J	16.4 U	16.4 U	38.4	38.4	63.4	59.9
Surrogate: TPT %Recovery	53.8	50.5	31.5	45.5	52.7		

U - Not detected, reported as MDL

J - Value below MDL

APPENDIX F: ANIMAL TEST

KEY

	<u>Sponsor Code</u>	<u>Description</u>
Oakland Outer Sediment, Upland	OAOUPCOMP	Composite of all replicates
Oakland Inner Sediment, Upland	OAIUPCOMP, Rep.1	Replicate 1 tissue
FVP 1 Comp,	BRHCOMP	Black Rock Harbor tissue
FVP 2 Comp,	BRHAMCOMP	Black Rock Harbor tissue
Reference Rep 1	MANR1	Manure Reference, Replicate 1 tissue

METALS CONCENTRATIONS IN PLANTS 10/30/91

METALS CONCENTRATIONS IN PLANTS

10/30/91

(concentrations in ug/g (ppm))

Sample Number	Sponsor Code	Cr	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb	Pb
		WF	WF	WF	WF	WF	WF	ICP-MS	ICP-MS	ICP-MS	WF	ICP-MS
WORMS												
347-1	BRHCOMP	124.3	12.2	168.2	166.7	6.07	4.66	3.400	7.260	0.765	32.1	22.8
347-2	BRHCOMP	83.1	7.46	190.5	150	8.27	4.96	3.100	5.050	0.445	17.5	13.5
347-3 REP 1	OALUPOOMP	79.4	11.57	19.2	107.1	11.83	3.34	0.102	3.580	0.780	2.62	1.64
347-3 REP 2	OALUPOOMP	67.5	10.42	20.4	112.1	12.41	3.61	0.099	3.650	0.078	2.46	1.63
347-4	OALUPOOMP	33.1	8.97	17.2	93.6	11.51	3.74	0.106	3.930	0.078	3.47	2.11
347-39	MANR1	3.2 U	1.85	22.7	175	4.51	3.13	0.032	5.390	0.044	2.3 U	0.872
347-40	MANR2	3.6 U	2.3	24.8	177.1	4.58	3.07	0.023	5.120	0.044	2.4 U	0.842
347-41	MANR3	3.7 U	1.08	23.5	162.9	4.91	3.41	0.005	1.900	0.011	2.1 U	0.226
347-42	MANR4	3.8	2.28	24.1	163.7	4.54	3.39	0.036	6.330	0.041	2.1 U	0.849

PLANTS

[illegible]

U - Indicates analyte not detected above detection limits.

347METALS DATA

METALS CONCENTRATIONS IN PLANTS 10/30/91

(concentrations in ug/g (ppm))

Sample Number	Sponsor Code	Cr	Ni	Cu	Zn	As	Se	Ag	Cd	Hg	Pb	Pb
		UFF	UFF	UFF	UFF	UFF	UFF	ICP/MS	ICP/MS	ICP/MS	UFF	ICP/MS
347-28	OAPR3SSE	8.7 U	2.46	9.4	17.4	0.87 U	0.65 U	0.016	0.063	0.051	2.2 U	0.584
347-29	OIR1SSE	8.2 U	1.60 U	7.91	17.1	0.83 U	0.66 U	0.015	0.046	0.063	2.1 U	0.288
347-30	OSSOOMPE	6.5 U	2.46	9.56	27.5	1.2 U	0.91 U	0.029	0.093	0.047	2.9 U	0.468
347-31	OOR1SSE	6.1 U	1.10 U	6.28	13.34	1.2 U	0.9 U	0.013	0.072	0.063	3.0 U	0.298
347-32	OOR2SSE	5.8 U	1.68	11.08	21.2	1.2 U	0.9 U	0.026	0.091	0.042	2.9 U	0.515
347-33	SAR1SSE	5.1 U	1.24	8.1	21	1.2 U	0.88 U	0.028	0.069	0.065	2.9 U	0.261
347-34	SAR2SSE	5.9 U	1.2 U	9.08	18.8	1.2 U	0.94 U	0.020	0.055	0.056	3.0 U	0.318
347-35	SAR3SSE	7.0 U	1.5 U	7.68	16.7	1.4 U	1.0 U	0.015	0.103	0.049	3.4 U	0.473
347-36	ERR1SS	6.4 U	1.3 U	6.88	18.7	1.2 U	0.94 U	0.036	0.033	0.058	3.0 U	0.173
347-37	ERR2SS	6.4 U	2.06	5.71	14.6	0.83 U	0.86 U	0.035	0.062	0.069	2.8 U	0.402
347-38	ERR3SS	6.6 U	1.3 U	11.9	27.1	0.95 U	0.96 U	0.026	0.074	0.048	3.1 U	0.388

PROCEDURAL BLANKS

Blank REP 1	NA	NA	NA	NA	NA	NA	NA	1.40	1.17	0.007	NA	0.93
Blank REP 2	NA	NA	NA	NA	NA	NA	NA	1.86	1.17	0.009	NA	1.4

NA = Not applicable.

U = Indicates analyte not detected above detection limits.

STANDARD REFERENCE MATERIAL

1566A-1	NA	NA	NA	NA	NA	NA	NA	1.49	3.9	0.06	NA	0.355
1566A-2	3.8 U	2.49	65.8	850	14.86	14.86	2.33	1.48	3.75	0.059	1.4 U	0.379
certified	1.43	2.25	66.3	830	14	14	2.21	1.68	4.15	0.064	0.37	0.371
value	±0.46	±0.44	±4.3	±57	±1.2	±1.2	±0.24	±0.15	±0.38	±0.0067	±0.014	±0.014
1571-1 REP 1	3.8 U	1.27	13.98	28.5	10.84	10.84	0.55 U	0.02	0.112	0.109	41.5	41.8
1571-1 REP 2	4.6	1.38	13.1	25.9	9.86	9.86	0.57 U	NA	NA	NA	42.2	NA
1571-2 REP1	4.7 U	1.47	13.27	28.7	8.05	8.05	0.41 U	0.02	0.108	0.108	44.0	41.5
1571-2 REP 2	4.3 U	1.32	14.01	25.4	9.1	9.1	0.43 U	NA	NA	NA	43.1	NA
certified	NC	1.3	12	25	14	14	0.08	NC	0.11	0.155	45	45
value	NC	±0.2	±1	±3	±2	±2	±0.01	NC	±0.02	±0.015	±3	±3

NA = Not applicable.

U = Indicates analyte not detected above detection limits.

NC = Not certified.

PAH CONCENTRATIONS IN
PLANT AND WORM TISSUE
(cf# 347)

(Concentrations in ug/kg wet wt)

Sponsor Code:

Sample Number

Species

Wet Weight(g)

METHOD BLANK

JM39PB

NA

10.000

BRHCOMP

347-01

EARTH WORM

6.513

BRHAMCOMP

347-02

EARTH WORM

2.474

OAIUPCOMP

347-03

EARTH WORM

4.069

OAQUPCOMP

347-04

EARTH WORM

7.987

OAP3R3SF

347-06

PLANT

4.188

OOSFOOMP

347-08

PLANT

1.903

naphthalene	17.088	2.73 JB	16.54 UB	4.49 JB	5.12 UB	26.24 B	21.5 UB
acenaphthylene	4.014 U	9.23	6.33 J	9.87 U	5.03 U	9.59 U	21.09 U
acenaphthene	0.981 J	3.33 U	8.76 U	3.74 J	1.46 J	3.22 J	11.39 U
fluorene	0.891 J	2.04 J	3.19 J	3.23 J	1.04 J	3.2 J	2.48 J
phenanthrene	2.467	24.25	19.66	16.86	4.75	6.2	5.95 J
anthracene	1.777 U	8.14	4.14 J	5.47	2.39	4.24 U	9.34 U
fluoranthene	0.169 J	32.48	25.25	38.07	12.26	3.17 J	2.75 J
pyrene	0.120 J	38.95	34.29	378.65	86.76	3.48 J	3.25 J
benz[a]anthracene	2.968 U	24.59	19.06	27.11	11.95	7.09 U	15.6 U
chrysene	2.080 U	183.54	132.87	57.42	22.52	1.19 J	1.35 J
benzo[b]fluoranthene	3.029 U	215.92	197.25	117.57	33.21	7.23 U	15.92 U
benzo[k]fluoranthene	2.537 U	139.62	90.2	95.5	25.08	6.06 U	13.33 U
benzo[a]pyrene	2.642 U	40.95 M	25.14 M	88.04 M	19.58 M	22.09 M	13.88 U
indeno[1,2,3-c,d]pyrene	3.167 U	4.86 U	12.8 U	7.78 U	3.97 U	7.56 U	16.64 U
dibenz[a,h]anthracene	2.154 U	1.78 J	8.71 U	5.29 U	2.7 U	5.14 U	11.32 U
benzo[g,h,i]perylene	4.295 U	6.6 U	12.67 J	10.59	5.38 U	10.26 U	22.57 U
naphthalene-d8 (% Rec)	73.65	80.29	60.49	66.63	54.28	63.74	61.24
acenaphthene-d10 (% Rec)	85.4 M	92.68 M	69.56 M	84.02 M	68.74 M	82.97 M	72.15 M
benzo[a]pyrene-d12 (% Rec)	61.34	80.29	43.85	63.62	45.52	76.03	68.74

* - Procedural Blank Reported In ng

ND - Non Detected

DO - Diluted Out

J - Value below MDL

U - Not Detected reported as MDL in ng/g

M - Matrix Interference

PAH CONCENTRATIONS IN
PLANT AND WORM TISSUE
(cf# 347)

(Concentrations in ug/kg wet wt)		MANR3	
Sponsor Code:		Sample Number	347-41
Species		EARTHWORM	
Wet Weight(g)		8.306	
naphthalene		4.93	UB
acenaphthylene		4.83	U
acenaphthene		1.33	J
fluorene		1.18	J
phenanthrene		3.2	J
anthracene		2.14	U
fluoranthene		0.48	J
pyrene		0.57	J
benz[a]anthracene		0.47	J
chrysene		0.88	J
benzo[b]fluoranthene		0.93	J
benzo[k]fluoranthene		0.78	J
benzo[a]pyrene		3.18	U
indeno[1,2,3-c,d]pyrene		3.81	U
dibenz[a,h]anthracene		2.59	U
benzo[g,h,i]perylene		5.17	U
naphthalene-d8 (% Rec)		64.75	
acenaphthene-d10 (% Rec)		82.23	M
benzo[a]pyrene-d12 (% Rec)		72.53	

* - Procedural Blank Reported in ng
 ND - Non Detected
 DO - Diluted Out
 J - Value below MDL
 U - Not Detected reported as MDL in ng
 M - Matrix Interference

WES BALDWIN (CF #347)
PCB/PESTICIDE RESULTS
IN TISSUE AND PLANT SAMPLES

11/14/91

(Concentrations in ug/kg (ppb) Wet Wt.)

Sponsor Code	Blank	BRHCOMP	BRHAMCOMP	OALUPCOMP	OACUPCOMP	OAP3SFCOMP	OAP3RSE	OOSFCOMP	BRHRISA
Sample ID	JM39PB	347-01	347-02	347-03	347-04	347-05	347-06	347-08	347-10
Species	NA	Worm	Worm	Worm	Worm	PLANT	PLANT	PLANT	PLANT
Wet Weight(g)	1.000	6.513	2.474	4.069	7.987	3.730	4.188	1.903	20.672
A-BHC	4.394	0.381 U	1.002 U	0.609 U	0.311 U	0.665 U	15.01 C	1.303 U	0.217 C
B-BHC	23.984	0.381 U	1.002 U	0.609 U	0.311 U	0.665 U	0.592 U	1.303 U	0.12 U
LINDANE	2.48 U	4.358	1.002 U	6.514	0.311 U	1.287	28.291	7.147	0.721
D-BHC	2.48 U	0.381 U	1.002 U	5.939	0.311 U	0.665 U	0.592 U	1.303 U	0.12 U
HEPTACHLOR	5.073 U	14.403 C	2.051 U	1.247 U	0.635 U	1.36 U	18.091 C	2.666 U	0.245 U
ALDRIN	5.179	6.796	0.979 U	1.225	6.65 C	3.004 C	40.421 C	2.767	0.528 C
HEPTACHLOREPOXIDE	2.779 U	0.427 U	1.123 U	1.215 C	0.945 C	0.745 U	0.664 U	1.46 U	0.134 U
A-ENDOSULFAN	18.349 C	11.696	19.831	2.634	1.35 C	3.272	4.457 C	2.752 JC	0.351 C
DIELDRIN	25.868 U	17.959	9.948 JC	4.716 JC	12.866	6.935 U	32.654	13.593 U	1.251 U
PPDDE	3.38 U	18.193 C	43.687 C	30.301 C	21.859 C	0.906 U	8.698 C	1.776 U	0.238 C
ENDRIN	24.397 U	3.746 U	9.861 U	5.996 U	5.905 C	6.541 U	5.825 U	12.82 U	1.18 U
B-ENDOSULFAN	1.445	1.092 U	13.6 C	2.298	6.244 C	1.906 U	2.336 C	3.736 U	0.344 U
PPDDT	1.671 U	9.29 C	40.587 C	29.311 C	25.619 C	0.448 U	6.103 C	0.878 U	0.081 U
ENDRIN ALDEHYDE	7.109 U	1.092 U	2.873 U	1.747 U	0.89 U	1.906 U	1.697 U	3.736 U	0.344 U
ENDOSULFAN SULFATE	7.109 U	1.092 U	28.155	11.899	9.327 C	1.906 U	1.326	3.736 U	0.344 U
PPDDT	5.215 U	9.278 C	2.108 U	2.613	1.22	1.398 U	10.89	2.74 U	0.252 U
TOXAPHENE	71.089 U	10.915 U	28.734 U	17.471 U	8.901 U	19.059 U	16.974 U	37.356 U	3.439 U
CHLORDANE	71.089 U	10.915 U	28.734 U	17.471 U	8.901 U	19.059 U	16.974 U	37.356 U	3.439 U
Aroclor 1242	71.089 U	10.915 U	28.734 U	17.471 U	8.901 U	19.059 U	16.974 U	37.356 U	3.439 U
Aroclor 1248	71.089 U	10.915 U	28.734 U	17.471 U	8.901 U	19.059 U	16.974 U	37.356 U	3.439 U
Aroclor 1254	71.089 U	2026.302 C	3289.12 C	320.121 C	104.985 C	19.059 U	16.974 U	37.356 U	3.439 U
Aroclor 1260	71.089 U	10.915 U	28.734 U	17.471 U	8.901 U	19.059 U	16.974 U	37.356 U	3.439 U
DBOFB (% Rec)	83	121 A	65	68	69	100	70	99	114
TCN (% Rec)	88	207 AM	131 A	87	59	65	75	101	124 A

B - Blank corrected
ND - Non Detected - Procedural Blank Reported in ng
DO - Diluted Out
J - Value below reporting limit
C - Detection confirmed on second column
& - Surrogate Recovery out of range

WES BALDWIN (CF #347)
PCB/PESTICIDE RESULTS
IN TISSUE AND PLANT SAMPLES

(Concentrations in ug/kg (ppb) Wet Wt.)										
Sponsor Code	SARUSSE	ERR1SS	ERR2SS	ERR3SS	MAN-R3	Matrix Spike	Matrix Spike			
Sample ID	347-35	347-36	347-37	347-38	347-41	347-11	347-11			
Species	PLANT	PLANT	PLANT	PLANT	Worm	PLANT	PLANT			
Wet Weight(g)	4.168	30.522	23.359	12.360	8.306	21.468				
A-BHC	0.441	0.081 U	0.106 U	0.201 U	0.304	3.823 C		103 C		
B-BHC	0.595 UB	0.081 U	0.106 U	0.201 U	0.299 UB	1.115 B		30 B		
LINDANE	3.887	0.966	0.558	2.011	0.299 U	9.178		76 .		
D-BHC	0.595 U	0.081 U	0.106 U	0.201 U	0.299 U	2.447 C		66 C		
HEPTACHLOR	1.217 U	0.166 U	0.217 U	0.41 U	0.611 U	4.092 C		110 C		
ALDRIN	1.177	0.314	0.362	0.374	0.635	2.791 C		66 C		
HEPTACHLORPOXIDE	0.667 U	0.091 U	0.119 U	0.225 U	0.335 U	2.734 C		70 C		
A-ENDOSULFAN	1.503 JC	0.645	0.465	0.535 J	0.954 C	1.956 C		45 C		
DIELDRIN	0.426	0.848 U	0.139 J	0.121 J	3.114 U	4.941 C		133 C		
PPDDE	1.66 C	1.244	0.743	0.615	0.562	3.433 C		92 C		
ENDRIN	5.953 U	0.799 U	1.043 U	1.974 U	2.937 U	7.254 JC		195 C&		
B-ENDOSULFAN	1.706 U	0.233 U	0.304 U	0.245 J	0.856 U	2.623 C		70 C		
PPDDD	0.401 U	0.055 U	0.071 U	0.135 U	0.201 U	3.965 C		106 C		
ENDRIN ALDEHYDE	1.708 U	0.233 U	0.304 U	0.575 U	0.858 U	0.331 U		0 ND		
ENDOSULFAN SULFATE	1.706 U	0.233 U	0.304 U	0.575 U	0.856 U	0.892 C		24 C&		
PPDDT	1.251 U	0.171 U	0.223 U	0.422 U	0.628 U	6.644 C		148 C		
TOXAPHENE	17.056 U	2.329 U	3.038 U	5.752 U	8.559 U	3.311 U				
CHLORDANE	17.056 U	2.329 U	3.038 U	5.752 U	8.559 U	3.311 U				
Aroclor 1242	17.056 U	2.329 U	3.038 U	5.752 U	8.559 U	3.311 U				
Aroclor 1248	17.056 U	2.329 U	3.038 U	5.752 U	8.559 U	3.311 U				
Aroclor 1254	17.056 U	2.329 U	3.038 U	5.752 U	8.559 U	909.199 C		98 C		
Aroclor 1260	17.056 U	2.329 U	3.038 U	5.752 U	8.559 U	3.311 U				
DBOFB (% Rec)	115	114	100	103	108			62		
TCN (% Rec)	115	94	80	104	103			101		

B - Blank corrected
ND - Non Detected * Procedural Blank Reported in ng
DO - Diluted Out
J - Value below reporting limit
C - Detection confirmed on second column.
& - Surrogate Recovery out of range

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13. ABSTRACT (Maximum 200 words) This report describes testing and evaluation performed by the Environmental Laboratory of the U.S. Army Engineer Waterways Experiment Station on sediment from Oakland Inner and Outer Harbor, California. Test protocols from the U.S. Environmental Protection Agency (EPA)/U.S. Army Corps of Engineers' Technical Framework for the Management of Dredged Material were used in the present evaluation to determine the potential for migration of contaminants into effluent, surface runoff, leachate, plants, and animals at an undetermined upland disposal site. One composite sediment each from Oakland Inner Harbor and Oakland Outer Harbor was tested. The composite sample consisted of sediment cores taken from the mud line to 44-ft depth. Both Oakland Harbor sediments had clayey sand textures. Total organic carbon concentrations in sediment from Oakland Inner and Outer Harbors were 3,364 and 6,042 mg/kg, respectively. (Continued)				
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13. Concluded.

Based on test results, Oakland Harbor sediments will require management of suspended solids in effluent and surface runoff and a mixing zone of at least 20 to 1 to meet the strictest assumed water quality criteria or standards. Management controls should be considered at the upland site, since plants grew poorly and contained elevated cadmium, lead, and selenium and earthworms accumulated arsenic, cadmium, and nickel.

cont

SUPPLEMENTARY

INFORMATION



REPLY TO
ATTENTION OF

CEWES-ES-F

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
3909 HALLS FERRY ROAD
VICKSBURG, MISSISSIPPI 39180-6199

11 March 1994

Errata Sheet

No. 1

EVALUATION OF UPLAND DISPOSAL
OF OAKLAND HARBOR, CALIFORNIA, SEDIMENT

Volume II

Inner and Outer Harbor Sediments

Final Report

Miscellaneous Paper EL-92-12

August 1993

1. Page 36 (Table II-4), page 37 (Table II-5), and page 39 (Table II-7):

Change primary column heading "Concentrations : g/kg dry weight" to read:

Concentrations $\mu\text{g/kg}$ dry weight

2. Page 68 (Table IV-3, Concluded):

Change primary column heading ("Inner Sediment") to read:

Table IV-3 (Concluded)

Outer Sediment

(Headings on first page of Table IV-3, page 67, remain unchanged.)

3. Page 96 (Table V-8):

Replace this page with the enclosed, corrected page.

ERRATA AD 9212999

Table V-8

Leachate pH and Conductivity (millisiemens) in Oakland Harbor

Sequential Batch Leachate Testing

Cycle	Anaerobic				Aerobic			
	Outer		Inner		Outer		Inner	
	pH	Conductivity	pH	Conductivity	pH	Conductivity	pH	Conductivity
1	7.33(0.09)	6.57(0.16)	7.40(0.04)	4.13(0.08)	7.37(0.03)	0.61(0.01)	7.10(0.13)	0.74(0.01)
2	7.15(0.05)	1.70(0.03)	7.68(0.05)	0.708(0.02)	7.43(0.14)	0.14(0.01)	7.40(0.09)	0.14(0.07)
3	7.20(0.12)	0.54(0.01)	7.81(0.06)	0.163(0.004)	7.47(0.06)	0.09(0)	6.93(.07)	0.06(0.002)
4	7.13(0.12)	0.18(0.02)	7.84(0.04)	0.094(0.001)	7.32(0.04)	0.07(0.005)	7.12(0.01)	0.05(0)
5	7.70(0.03)	0.19(0.04)	7.55(0.15)	0.08(0.005)	6.83(0.03)	0.05(0)	6.78(0.04)	0.04(0)
6	7.13(0.03)	0.10(0.003)	7.53(0.08)	0.061(0.001)	6.53(0.03)	0.06(0)	7.20(0)	0.03(0.003)

* Standard error in parentheses.